Gratitude

In appreciation and gratitude

to The Custodian of the Two Holy Mosques

King Abdullah Bin Abdul Aziz Al Saud

And

H.R.H. Prince Sultan Bin Abdul Aziz Al Saud

Crown Prince, Deputy Premier, Minister of Defence

& Aviation and Inspector General

For their continuous support and gracious consideration,

the Saudi Building Code National Committee (SBCNC)

is honored to present the first issue of

the Saudi Building Code (SBC).

Saudi Building Code Requirements

201	Architectural	
301	Structural – Loading and Forces	
302	Structural – Testing and Inspection	
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PREFACE

The Saudi Building Code (SBC) is a set of legal, administrative and technical regulations and requirements that specify the minimum standards of construction for building in order to ensure public safety and health. A Royal Decree dated 11th June 2000 order the formation of a national committee composed of representatives of Saudi universities and governmental and private sectors. In September 2001, the Council of Ministers approved the general plan of the National Committee to develop a national building code for the Kingdom of Saudi Arabia.

To choose a base code for the Saudi Building Code, a number of Codes have been studied. The National Committee has been acquainted with the results of the national researches and the international codes from the U.S.A., Canada and Australia, also, the European Code, and Arab Codes. It has also sought the opinions of specialists in relevant Saudi universities, governmental and private sectors through holding a questionnaire, a symposium and specialized workshops, in the light of which, (ICC) has been chosen to be a base code for the Saudi Building Code.

The International Code Council (ICC) grants permission to the Saudi Building Code National Committee (SBCNC) to include all or any portion of material from the ICC codes, and standards in the SBC and ICC is not responsible or liable in any way to SBCNC or to any other party or entity for any modifications or changes that SBCNC makes to such documents.

Toward expanding the participation of all the specialists in the building and construction industry in the Kingdom through the governmental and private sectors, the universities and research centers, the National Committee took its own decisions related to code content by holding specialized meetings, symposiums and workshops and by the help of experts from inside and outside of Saudi Arabia.

The technical committees and sub-committees started their work in April 2003 to develop the Saudi Building Code that adapts the base code with the social and cultural environment, the natural and climatic conditions, types of soil and properties of materials in the Kingdom

The Saudi Building Code Structural Requirements for Masonry Construction (SBC 305) were developed based on ICC code in addition to American Concrete Institute (ACI) materials. ACI grants permission to the SBCNC to include ACI materials in the SBC, and ACI is not responsible for any modifications or changes that SBCNC has made to accommodate local conditions.

The development process of SBC 305 followed the methodology approved by the Saudi Building Code National Committee. Many changes and modifications were made on the base code and only SI units were used throughout the Code. The changes were intended to compose a comprehensive set of provisions, to the best possible extent, for materials, environmental conditions, and construction practices prevailing in the Kingdom.

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SBC 305 was reviewed and significantly revised by special technical committee during the period Aug.-Sept. 2007. The committee members are:

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SCOPE

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SECTION 1.2
DESIGN METHODS

1.2.0 Masonry shall comply with the provisions of one of the following design methods in this code as well as the requirements of Chapter 1 through Chapter 4. Masonry designed by the working stress design provisions of Section 1.2.1, the strength design provisions of Section 1.2.2 or the seismic provisions of Section 1.2.3 shall comply with Chapter 5.

1.2.1 **Working stress design.** Masonry designed by the working stress design method shall comply with the provisions of Chapter 6 and Chapter 7.

1.2.2 **Strength design.** Masonry designed by the strength design method shall comply with the provisions of Chapter 6 and Chapter 8.

1.2.3 **Seismic design.** Masonry shall be designed in accordance with Chapter 6. Special inspection during construction shall be provided as set forth in SBC 302.

1.2.4 **Empirical design.** Masonry designed by the empirical design method shall comply with the provisions of Chapter 6 and Chapter 9.

1.2.5 **Glass masonry.** Glass masonry shall comply with the provisions of Chapter 10.

1.2.6 **Masonry veneer.** Masonry veneer shall comply with the provisions of Chapter 14.

SECTION 1.3
CONSTRUCTION DOCUMENTS

1.3.0 The construction documents shall show all of the items required by this code including the following:

1. Specified size, grade, type and location of reinforcement, anchors and wall ties.
2. Reinforcing bars to be welded and welding procedure.
3. Size and location of structural elements.
4. Provisions for dimensional changes resulting from elastic deformation, creep, shrinkage, temperature and moisture.
5. All loads used in the design of masonry.
6. Specified compressive strength of masonry at stated ages or stages of construction for which masonry is designed, except where specifically exempted by Code provisions.
7. Size and location of conduits, pipes, and sleeves.

1.3.1 **Fireplace drawings.** The construction documents shall describe in sufficient detail the location, size and construction of masonry fireplaces. The thickness and characteristics of materials and the clearances from walls, partitions and ceilings shall be clearly indicated.

1.3.2 The construction documents shall be consistent with design assumptions.

1.3.3 Construction documents shall specify the minimum level of quality assurance as defined in Chapter 5, or shall include an itemized quality assurance program that exceeds the requirements of Chapter 5.

1.3.4 Calculations pertinent to design shall be filed with the drawings when required by the building official. When automatic data processing is used, design assumptions, program documentation and identified input and output data may be submitted in lieu of calculations.

1.3.5 **Approval of special systems of design or construction.** Sponsors of any system of design or construction within the scope of this Code, the adequacy of which has been shown by successful use or by analysis or test, but that does not conform to or is not covered by this Code, shall have the right to present the data on which their design is based to a board of examiners appointed by the building official. The board shall be composed of registered engineers and shall have authority to investigate the data so submitted, to require tests, and to formulate rules governing design and construction of such systems to meet the intent of this Code. The rules, when approved and promulgated by the building official, shall be of the same force and effect as the provisions of this Code.

SECTION 1.4
LOADING

1.4.1 **General.** Masonry shall be designed to resist applicable loads.

1.4.2 **Load provisions.** Service loads shall be in accordance with SBC 301 with such live load reductions as are permitted in SBC 301.

1.4.3 **Lateral load resistance.** Buildings shall be provided with a structural system designed to resist wind and earthquake loads and to accommodate the effect of the resulting deformation.

1.4.4 **Other effects.** Consideration shall be given to effects of forces and deformations due to prestressing, vibrations, impact, shrinkage, expansion, temperature changes, creep, unequal settlement of supports, and differential movement.

1.4.5 **Lateral load distribution.** Lateral loads shall be distributed to the structural system in accordance with member stiffnesses and shall comply with the requirements of this section.

1.4.5.1 Flanges of intersecting walls designed in accordance with Section 3.13.4.2 shall be included in stiffness determination.

1.4.5.2 Distribution of load shall be consistent with the forces resisted by foundations.

1.4.5.3 Distribution of load shall include the effect of horizontal torsion of the structure due to eccentricity of wind or seismic loads resulting from the non-uniform distribution of mass.

CHAPTER 2
DEFINITIONS AND NOTATIONS

SECTION 2.1
DEFINITIONS

2.1.0 The following words and terms shall have the meanings shown herein.

ADOBE CONSTRUCTION. Construction in which the exterior load-bearing and non-load-bearing walls and partitions are of unfired clay masonry units.

Adobe, stabilized. Unfired clay masonry units to which admixtures such as emulsified asphalt, are added during the manufacturing process to limit the units' water absorption so as to increase their durability.

Adobe, unstabilized. Unfired clay masonry units that do not meet the definition of "Adobe, stabilized."

ANCHOR. Metal rod, wire or strap that secures masonry to its structural support.

Anchor pullout. Anchor failure defined by the anchor sliding out of the material in which it is embedded without breaking out a substantial portion of the surrounding material.

ARCHITECTURAL TERRA COTTA. Plain or ornamental hard-burned modified clay units, larger in size than brick, with glazed or unglazed ceramic finish.

AREA.

Bedded. The area of the surface of a masonry unit that is in contact with mortar in the plane of the joint.

Gross cross-sectional. The area delineated by the out-to-out specified dimensions of masonry in the plane under consideration.

Net cross-sectional. The area of masonry units, grout and mortar crossed by the plane under consideration based on out-to-out specified dimensions.

BACKING. The wall or surface to which the veneer is secured.

BED JOINT. The horizontal layer of mortar on which a masonry unit is laid.

BOND BEAM. A horizontal grouted element within masonry in which reinforcement is embedded.

BOND REINFORCING. The adhesion between steel reinforcement and mortar or grout.

BRICK.

Calcium silicate (sand lime brick). A masonry unit made of sand and lime.

Clay or shale. A masonry unit made of clay or shale, usually formed into a rectangular prism while in the plastic state and burned or fired in a kiln.

Concrete. A masonry unit having the approximate shape of a rectangular prism and composed of inert aggregate particles embedded in a hardened cementitious matrix.

BUTTRESS. A projecting part of a masonry wall built integrally therewith to provide lateral stability.

CAST STONE. A building stone manufactured from Portland cement concrete precast and used as a trim, veneer or facing on or in buildings or structures.

CAMBER. A deflection that is intentionally built into a structural element to improve appearance or to nullify the deflection of the element under the effects of loads, shrinkage and creep.

CELL. A void space having a gross cross-sectional area greater than 950 mm^2.

CHIMNEY. A primarily vertical enclosure containing one or more passageways for conveying flue gases to the outside atmosphere.

CHIMNEY TYPES.

High-heat appliance type. An approved chimney for removing the products of combustion from fuel-burning, high-heat appliances producing combustion gases in excess of 1100^{o}C measured at the appliance flue outlet see Section 13.11.3.

Low-heat appliance type. An approved chimney for removing the products of combustion from fuel-burning, low-heat appliances producing combustion gases not in excess of 540^{o}C under normal operating conditions, but capable of producing combustion gases of 760^{o}C during intermittent forces firing for periods up to 1 hour. Temperatures shall be measured at the appliance flue outlet.

Masonry type. A field-constructed chimney of solid masonry units or stones.

Medium-heat appliance type. An approved chimney for removing the products of combustion from fuel-burning, medium-heat appliances producing combustion gases not exceeding 1100^{o}C measured at the appliance flue outlet see Section 13.11.2.

CLEANOUT. An opening to the bottom of a grout space of sufficient size and spacing to allow the removal of debris.

COLLAR JOINT. Vertical longitudinal joint between wythes of masonry or between masonry and backup construction that is permitted to be filled with mortar or grout.

COLUMN, MASONRY. An isolated vertical member whose horizontal dimension measured at right angles to its thickness does not exceed three times its thickness and whose height is at least four times its thickness.

COMPOSITE ACTION. Transfer of stress between components of a member designed so that in resisting loads, the combined components act together as a single member.

COMPOSITE MASONRY. Multiwythe masonry members acting with composite action.

COMPRESSIVE STRENGTH OF MASONRY. Maximum compressive force resisted per unit of net cross-sectional area of masonry, determined by the testing of masonry prisms or a function of individual masonry units, mortar and grout.

CONNECTOR. A mechanical device for securing two or more pieces, parts or members together, including anchors, wall ties and fasteners.

COVER. Distance between surface of reinforcing bar and edge of member.

DEPTH. The dimension of a member measured in the plane of a cross section perpendicular to the neutral axis.

DESIGN STORY DRIFT. The difference of deflections at the top and bottom of the story under consideration, calculated by multiplying the deflections determined from an elastic analysis by the appropriate deflection amplification factor, C_d from SBC 301.

DIAPHRAGM. A roof or floor system designed to transmit lateral forces to shear walls or other lateral-load-resisting elements.

DIMENSIONS.

Actual. The measured dimension of a masonry unit or element.

Nominal. A dimension equal to a specified dimension plus an allowance for the joints with which the units are to be laid. Thickness is given first, followed by height and then length.

Specified. The dimensions specified for the manufacture or construction of masonry, masonry units, joints or any other component of a structure.

EFFECTIVE HEIGHT. For braced members, the effective height is the clear height between lateral supports and is used for calculating the slenderness ratio. The effective height for unbraced members is calculated in accordance with engineering mechanics.

FIREPLACE. A hearth and fire chamber or similar prepared place in which a fire may be made and which is built in conjunction with a chimney.

FIREPLACE THROAT. The opening between the top of the firebox and the smoke chamber.

FOUNDATION PIER. An isolated vertical foundation member whose horizontal dimension measured at right angles to its thickness does not exceed 3 times its thickness and whose height is equal to or less than 4 times its thickness.

GROUTED MASONRY.

Grouted hollow-unit masonry. That form of grouted masonry construction in which certain designated cells of hollow units are continuously filled with grout.

Grouted multiwythe masonry. That form of grouted masonry construction in which the space between the wythes is solidly or periodically filled with grout.

HEAD JOINT. Vertical mortar joint placed between masonry units within the wythe at the time the masonry units are laid.

HEADER (Bonder). A masonry unit that connects two or more adjacent wythes of masonry.

HEIGHT, WALLS. The vertical distance from the foundation wall or other immediate support of such wall to the top of the wall.

MASONRY. A built-up construction or combination of building units or materials of clay, shale, concrete, glass, gypsum, stone or other approved units bonded together with or without mortar or grout or other accepted method of joining.

Ashlar masonry. Masonry composed of various sized rectangular units having sawed, dressed or squared bed surfaces, properly bonded and laid in mortar.

Coursed ashlar. Ashlar masonry laid in courses of stone of equal height for each course, although different courses shall be permitted to be of varying height.

Glass unit masonry. Nonload-bearing masonry composed of glass units bonded by mortar.

Plain masonry. Masonry in which the tensile resistance of the masonry is taken into consideration and the effects of stresses in reinforcement are neglected.

Random ashlar. Ashlar masonry laid in courses of stone set without continuous joints and laid up without drawn patterns. When composed of material cut into modular heights, discontinuous but aligned horizontal joints are discernible.

Reinforced masonry. Masonry construction in which reinforcement acting in conjunction with the masonry is used to resist forces.

Solid masonry. Masonry consisting of solid masonry units laid contiguously with the joints between the units filled with mortar.

Veneer, masonry. A masonry wythe that provides the exterior finish of a wall system and transfer out-of-plane load directly to a backing, but is not considered to add load resisting capacity to the wall system.

MASONRY UNIT. Brick, tile, stone, glass block or concrete block conforming to the requirements specified in Chapter 3.

Clay. A building unit larger in size than a brick, composed of burned clay, shale, fired clay or mixtures thereof.

Concrete. A building unit or block larger in size than 300 mm by 100 mm by 100 mm made of cement and suitable aggregates.

Hollow. A masonry unit whose net cross-sectional area in any plane parallel to the load-bearing surface is less than 75% of its gross cross-sectional area measured in the same plane.

Solid. A masonry unit whose net cross-sectional area in every plane parallel to the load-bearing surface is 75% or more of its gross cross-sectional area measured in the same plane.

MEAN DAILY TEMPERATURE. The average daily temperature of temperature extremes predicted by a local weather bureau for the next 24 hours.

MORTAR. A plastic mixture of approved cementitious materials, fine aggregates and water used to bond masonry or other structural units.

MORTAR, SURFACE-BONDING. A mixture to bond concrete masonry units that contains hydraulic cement, glass fiber reinforcement with or without inorganic fillers or organic modifiers and water.

PLASTIC HINGE. The zone in a structural member in which the yield moment is anticipated to be exceeded under loading combinations that include earthquakes.

PRISM. An assemblage of masonry units and mortar with or without grout used as a test specimen for determining properties of the masonry.

RUBBLE MASONRY. Masonry composed of roughly shaped stones.

Coursed rubble. Masonry composed of roughly shaped stones fitting approximately on level beds and well bonded.

Random rubble. Masonry composed of roughly shaped stones laid without regularity of coursing but well bonded and fitted together to form well-divided joints.

Rough or ordinary rubble. Masonry composed of unsquared field stones laid without regularity of coursing but well bonded.

RUNNING BOND. The placement of masonry units such that head joints in successive courses are horizontally offset at least one-quarter the unit length.

SHEAR WALL.

Detailed plain masonry shear wall. A masonry shear wall designed to resist lateral forces neglecting stresses in reinforcement, and designed in accordance with 6.1.1.2.

Intermediate reinforced masonry shear wall. A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with 6.1.1.4.

Ordinary plain masonry shear wall. A masonry shear wall designed to resist lateral forces neglecting stresses in reinforcement, and designed in accordance with 6.1.1.1.

Ordinary reinforced masonry shear wall. A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with 6.1.1.3.

Special reinforced masonry shear wall. A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with 6.1.1.5.

SHELL. The outer portion of a hollow masonry unit as placed in masonry.

SPECIFIED. Required by construction documents.

SPECIFIED COMPRESSIVE STRENGTH OF MASONRY, $f_m^{'}$. Minimum compressive strength, expressed as force per unit of net cross-sectional area, required of the masonry used in construction by the construction documents, and upon which the project design is based. Whenever the quantity $f_m^{'}$ is under the radical sign, the square root of numerical value only is intended and the result has units of MPa.

STACK BOND. The placement of masonry units in a bond pattern is such that head joints in successive courses are vertically aligned. For the purpose of this code, requirements for stack bond shall apply to masonry laid in other than running bond.

STONE MASONRY. Masonry composed of field, quarried or cast stone units bonded by mortar.

Ashlar stone masonry. Stone masonry composed of rectangular units having sawed, dressed or squared bed surfaces and bonded by mortar.

Rubble stone masonry. Stone masonry composed of irregular-shaped units bonded by mortar.

STRENGTH.

Design strength. Nominal strength multiplied by a strength reduction factor.

Nominal strength. Strength of a member or cross-section calculated in accordance with these provisions before application of any strength-reduction factors.

Required strength. Strength of a member or cross section required to resist factored loads.

TIE, LATERAL. Loop of reinforcing bar or wire enclosing longitudinal reinforcement.

TIE, WALL. A connector that connects wythes of masonry walls together.

TILE. A ceramic surface unit, usually relatively thin in relation to facial area, made from clay or a mixture of clay or other ceramic materials, called the body of the tile, having either a “glazed” or “unglazed” face and fired above red heat in the course of manufacture to a temperature sufficiently high enough to produce specific physical properties and characteristics.

TRANSVERSE REINFORCEMENT. Reinforcement placed perpendicular to the axis of the member.

UNREINFORCED MASONRY. Masonry in which the tensile resistance of masonry is taken into consideration and the resistance of the reinforcing steel is neglected.

TILE, STRUCTURAL CLAY. A hollow masonry unit composed of burned clay, shale, fire clay or mixture thereof, and having parallel cells.

VENEER, ADHERED. Masonry veneer secured to and supported by the backing through adhesion.

VENEER, ANCHORED. Masonry veneer secured to and supported laterally by the backing through anchors and supported vertically by the foundation or other structural elements.

WALL. A vertical element with a horizontal length-to-thickness ratio greater than three, used to enclose space.

Cavity wall. A wall built of masonry units or of concrete, or a combination of these materials, arranged to provide an airspace within the wall, and in which the inner and outer parts of the wall are tied together with metal ties.

Composite wall. A wall built of a combination of two or more masonry units bonded together, one forming the backup and the other forming the facing elements.

Dry-stacked, surface-bonded walls. A wall built of concrete masonry units where the units are stacked dry, without mortar on the bed or head joints, and where both sides of the wall are coated with a surface-bonding mortar.

Masonry-bonded hollow wall. A wall built of masonry units so arranged as to provide an airspace within the wall, and in which the facing and backing of the wall are bonded together with masonry units.

Parapet wall. The part of any wall entirely above the roof line.

WEB. An interior solid portion of a hollow masonry unit as placed in masonry.

WYTHE. Each continuous, vertical section of a wall, one masonry unit in thickness.

SECTION 2.2
NOTATIONS

A_b	=	Cross-sectional area of an anchor bolt, mm^2
A_g	=	Gross cross-sectional area of masonry, mm^2
A_n	=	Net cross-sectional area of masonry, mm^2
A_p	=	Projected area on the masonry surface of a right circular cone for anchor bolt allowable shear and tension calculations, mm^2
A_{pt}	=	Projected area on masonry surface of a right circular cone for calculating tensile breakout capacity of anchor bolts, mm^2
A_{pv}	=	Projected area on masonry surface of one-half of a right circular cone for calculating shear breakout capacity of anchor bolts, mm^2
A_s	=	Effective cross-sectional area of reinforcement, mm^2
A_v	=	Cross-sectional area of shear reinforcement, mm^2
A_1	=	Bearing area, mm^2
A_2	=	Effective bearing area, mm^2
A_{st}	=	Total area of laterally tied longitudinal reinforcing steel in a reinforced masonry column or pilaster, mm^2
α	=	Depth of an equivalent compression zone at nominal strength, mm
B_a	=	Allowable axial force on an anchor bolt, N
B_{an}	=	Nominal axial strength of an anchor bolt, N
B_v	=	Allowable shear force on an anchor bolt, N
B_{vn}	=	Nominal shear strength of an anchor bolt, N
b	=	Effective width of rectangular member or width of flange for T and I sections, mm
b_a	=	Total applied design axial force on an anchor bolt, N
b_{af}	=	Factored axial force in an anchor bolt, N
b_v	=	Total applied design shear force on an anchor bolt, N
b_{vf}	=	Factored shear force in an anchor bolt, N
b_w	=	Width of wall beam, mm
C_d	=	Deflection amplification factor
c	=	Distance from the fiber of maximum compressive strain to the neutral axis, mm
D	=	Dead load or related internal moments and forces
d	=	Distance from extreme compression fiber to centroid of tension reinforcement, mm
d_b	=	Nominal diameter of reinforcement or anchor bolt, mm
d_v	=	Actual depth of masonry in direction of shear considered, mm
E	=	Load effects of earthquake or related internal moments and forces
E_m	=	Modulus of elasticity of masonry in compression, MPa
E_s	=	Modulus of elasticity of steel, MPa
E_v	=	Modulus of rigidity (shear modulus) of masonry, MPa
e	=	Eccentricity of axial load, mm
e_b	=	Projected leg extension of bent-bar anchor measured from inside edge of anchor at bend to farthest point of anchor in the plane of the hook, mm
e_u	=	Eccentricity of P_{uf}, mm

F_{α} = Allowable compressive stress due to axial load only, MPa
F_b = Allowable compressive stress due to flexure only, MPa
F_s = Allowable tensile or compressive stress in reinforcement, MPa
F_v = Allowable shear stress in masonry, MPa
f_a = Calculated compressive stress in masonry due to axial load only, MPa
$f_g^{'}$ = Specified compressive strength of grout, MPa
$f_m^{'}$ = Specified compressive strength of masonry at age of 28 days, MPa
f_r = Modulus of rupture, MPa
f_s = Calculated tensile or compressive stress in reinforcement, MPa
f_v = Calculated shear stress in masonry, MPa
fy = Specified yield stress of the reinforcement or the anchor bolt, MPa
H = Lateral pressure of soil or related internal moments and forces
h = Effective height of column, wall, or pilaster, mm
I_{cr} = Moment of inertia of cracked cross-sectional area of a member, mm^4
I_{eff} = Effective moment of inertia, mm^4
I_g = Moment of inertia of gross cross-sectional area of a member, mm^4
I_n = Moment of inertia of net cross-sectional area of a member, mm^4
j = Ratio of distance between centroid of flexural compressive forces and centroid of tensile forces to depth, d
K = The lesser of the masonry cover, clear spacing between adjacent reinforcement, or five times d_b, mm
k_c = Coefficient of creep of masonry, per MPa
k_e = Coefficient of irreversible moisture expansion of clay masonry
k_m = Coefficient of shrinkage of concrete masonry
k_t = Coefficient of thermal expansion of masonry per degree Celsius
L = Live load or related internal moments and forces
L_s = Distance between supports, mm
L_w = Length of wall, mm
l = Clear span between supports, mm
l_b = Effective embedment length of plate, headed or bent anchor bolts, mm
l_{be} = Anchor bolt edge distance, measured in the direction of load, from edge of masonry to center of the cross section of anchor bolt, mm
l_d = Required development length of reinforcement, mm
l_{de} = Embedment length of reinforcement, mm
l_e = Equivalent embedment length provided by standard hooks, mm
M = Maximum moment at the section under consideration, N-mm
M_{α} = Maximum moment in member due to the applied loading for which deflection is computed, N-mm
M_{cr} = Nominal cracking moment strength, N-mm
M_n = Nominal moment strength, N-mm
M_{ser} = Service moment at midheight of a member, including P-delta effects, N-mm
M_u = Factored moment, N-mm
N_v = Compressive force acting normal to shear surface, N
P = Axial load, N
P_a = Allowable compressive force in reinforced masonry due to axial load, N
P_e = Euler buckling load, N
P_n = Nominal axial strength, N
P_u = Factored axial load, N
P_{uf} = Factored load from tributary floor or roof areas, N

P_{uw}	=	Factored weight of wall area tributary to wall section under consideration, N
Q	=	First moment about the neutral axis of a section of that portion of the cross section lying between the neutral axis and extreme fiber, mm^3
R	=	Seismic response modification factor
r	=	Radius of gyration, mm
S_n	=	Section modulus of the net cross-sectional area of a member, mm^3
s	=	Spacing of reinforcement, mm
S_l	=	Total linear drying shrinkage of concrete masonry units determined in accordance with ASTM C 426.
T	=	Forces and moments caused by restraint of temperature, shrinkage, and creep strains or differential movements
t	=	Specified wall thickness dimension or the least lateral dimension of a column, mm
v	=	Shear stress, MPa
V	=	Shear force, N
V_m	=	Shear strength provided by masonry, N
V_n	=	Nominal shear strength, N
V_u	=	Required shear strength due to factored loads, N
V_s	=	Shear strength provided by shear reinforcement, N
W	=	Wind load, or related internal moments and forces
w_u	=	Out-of-plane factored uniformly distributed load, N/mm
β	=	0.25 for fully grouted masonry or 0.15 for other than fully grouted masonry
β_b	=	Ratio of area of reinforcement cut off to total area of tension reinforcement at a section
γ	=	Reinforcement size factor
Δ	=	Calculated story drift, mm
Δ_α	=	Allowable story drift, mm
δ_s	=	Horizontal deflection at midheight under service loads, mm
δ_u	=	Deflection due to factored loads, mm
ε_{mu}	=	Maximum usable compressive strain of masonry
ϕ	=	Strength reduction factor
ρ_{max}	=	Maximum reinforcement ratio
ρ_n	=	Ratio of distributed shear reinforcement on plane perpendicular to plane of A_{mv}

CHAPTER 3
MASONRY CONSTRUCTION MATERIALS

SECTION 3.1
CONCRETE MASONRY UNITS

3.1.0 Concrete masonry units shall conform to the following standards: ASTM C 55 for concrete brick; ASTM C 73 for calcium silicate face brick; ASTM C 90 for load-bearing concrete masonry units or ASTM C 744 for prefaced concrete and calcium silicate masonry units.

SECTION 3.2
CLAY OR SHALE MASONRY UNITS

3.2.0 Clay or shale masonry units shall conform to the following standards: ASTM C 34 for structural clay load-bearing wall tile; ASTM C 56 for structural clay nonload-bearing wall tile; ASTM C 62 for building brick (solid masonry units made from clay or shale); ASTM C 1088 for solid units of thin veneer brick; ASTM C 126 for ceramic-glazed structural clay facing tile, facing brick and solid masonry units; ASTM C 212 for structural clay facing tile; ASTM C 216 for facing brick (solid masonry units made from clay or shale) and ASTM C 652 for hollow brick (hollow masonry units made from clay or shale).

Exception: Structural clay tile for nonstructural use in fire-proofing of structural members and in wall furring shall not be required to meet the compressive strength specifications. The fire-resistance rating shall be determined in accordance with ASTM E 119.

SECTION 3.3
STONE MASONRY UNITS

3.3.0 Stone masonry units shall conform to the following standards: ASTM C 503 for marble building stone (exterior): ASTM C 568 for limestone building stone; ASTM C 615 for granite building stone; ASTM C 616 for sandstone building stone or ASTM C 629 for slate building stone.

SECTION 3.4
CERAMIC TILE

3.4.0 Ceramic tile shall be as defined in, and shall conform to the requirements of ANSI A137.1.

SECTION 3.5
GLASS UNIT MASONRY

3.5.0 Hollow glass units shall be partially evacuated and have a minimum average glass face thickness of 5 mm. Solid glass-block units shall be provided when required. The surfaces of units intended to be in contact with mortar shall be treated with a polyvinyl butyral coating or latex-based paint. Reclaimed units shall not be used.

SECTION 3.6
SECOND-HAND UNITS

3.6.0 Second-hand masonry units shall not be reused unless they conform to the requirements of new units. The units shall be of whole, sound materials and free from cracks and other defects that will interfere with proper laying or use. Old

mortar shall be cleaned from the unit before reuse.

SECTION 3.7
MORTAR

3.7.0 Mortar for use in masonry construction shall conform to ASTM C 270 and shall conform to the proportion specifications of Table 3.7.1 or the property specifications of Table 3.7.2. Type S or N mortar shall be used for glass unit masonry. The amount of water used in mortar for glass unit masonry shall be adjusted to account for the lack of absorption. Retempering of mortar for glass unit masonry shall not be permitted after initial set. Unused mortar shall be discarded within 2½ hours after initial mixing except that unused mortar for glass unit masonry shall be discarded within 1½ hours after initial mixing.

TABLE 3.7.1
MORTAR PROPORTIONS

Mortar	Type	PROPORTIONS BY VOLUME (cementitious Materials)							HYDRATED LIME[e] OR LIME PUTTY	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
		Portland cement[a] or blended cement[b]	Masonry cement[c]			Mortar cement[d]				
			M	S	N	M	S	N		
Cement-lime	M	1	—	—	—	—	—	—	¼	Not less than 2¼ and not more than 3 times the sum of the separate volumes of cementitious materials
	S	1	—	—	—	—	—	—	Over ¼ to ½	
	N	1	—	—	—	—	—	—	Over ½ to 1¼	
	O	1	—	—	—	—	—	—	Over 1¼ to 2½	
Mortar cement	M	1	—	—	—	—	—	1	—	
	M	—	—	—	—	1	—	—	—	
	S	½	—	—	—	—	—	1	—	
	S	—	—	—	—	—	1	—	—	
	N	—	—	—	—	—	—	1	—	
	O	—	—	—	—	—	—	1	—	
Masonry cement	M	1	—	—	1	—	—	—	—	
	M	—	1	—	—	—	—	—	—	
	S	½	—	—	1	—	—	—	—	
	S	—	—	1	—	—	—	—	—	
	N	—	—	—	1	—	—	—	—	
	O	—	—	—	1	—	—	—	—	

a. Portland cement conforming to the requirements of ASTM C 150.
b. Blended cement conforming to the requirements of ASTM C 595.
c. Masonry cement conforming to the requirements of ASTM C 91.
d. Mortar cement conforming to the requirements of ASTM C 1329.
e. Hydrated lime conforming to the requirements of ASTM C 207.

SECTION 3.8
SURFACE-BONDING MORTAR

3.8.0 Surface-bonding mortar shall comply with ASTM C 887. Surface bonding of concrete masonry units shall comply with ASTM C 946.

SECTION 3.9
MORTARS FOR CERAMIC WALL AND FLOOR TILE

3.9.0 Portland cement mortars for installing ceramic wall and floor tile shall comply with ANSI A108.1A and ANSI A108.1B and be of the compositions indicated in Table 3.9.1.

TABLE 3.7.2
MORTAR PROPERTY[a]

MORTAR	TYPE	AVERAGE COMPRESSIVE[b] STRENGTH AT 28 DAYS Minimum (MPa)	WATER RETENTION Minimum (%)	AIR CONTENT Minimum (%)
Cement-lime	M	17.25	75	12
	S	12.25	75	12
	N	5.0	75	14[c]
	O	2.25	75	14[c]
Mortar cement	M	17.25	75	12
	S	12.25	75	12
	N	5.0	75	14[c]
	O	2.25	75	14[c]
Masonry cement	M	17.25	75	18
	S	12.25	75	1
	N	5.0	75	20[d]
	O	2.25	75	20[d]

a. This aggregate ratio (measured in damp, loose condition) shall not be less than 2$^1/_4$ and not more than 3 times the sum of the separate volumes of cementitious materials.
b. In accordance with ASTM C 270.
c. When structural reinforcement is incorporated in cement-lime or mortar cement mortars, the maximum air content shall not exceed 12 %.
d. When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall not exceed 18 percent.

TABLE 3.9.1
CERAMIC TILE MORTAR COMPOSITIONS

LOCATION	MORTAR	COMPOSITION
Walls	Scratchcoat	1 cement; $^1/_5$ hydrated lime; 4 dry or 5 damp sand
	Setting bed and Leveling coat	1 cement; ½ hydrated lime; 5 damp sand to 1 cement 1 hydrated lime, 7 damp sand
Floors	Setting bed	1 cement; $^1/_{10}$ hydrated lime; 5 dry or 6 damp sand; or 1 cement; 5 dry or 6 damp sand
Ceilings	Scratchcoat and sand bed	1 cement; ½ hydrated lime; 2½ dry sand or 3 damp sand

3.9.1 **Dry-set Portland cement mortars.** Premixed prepared Portland cement mortars, which require only the addition of water and are used in the installation of ceramic tile, shall comply with ANSI A118.1. The shear bond strength for tile set in such mortar shall be as required in accordance with ANSI A118.1. Tile set in dry-set Portland cement mortar shall be installed in accordance with ANSI A108.5.

3.9.2 **Electrically conductive dry-set mortars.** Pre-mixed prepared Portland cement mortars, which require only the addition of water and comply with ANSI A118.2, shall be used in the installation of electrically conductive ceramic tile. Tile set in electrically conductive dry-set mortar shall be installed in accordance with ANSI A108.7.

3.9.3 **Latex-modified Portland cement mortar.** Latex-modified Portland cement thin-set mortars in which latex is added to dry-set mortar as a replacement for all or part of the gauging water that are used for the installation of ceramic tile shall comply with ANSI A118.4. Tile set in latex-modified Portland cement shall be installed in accordance with ANSI A108.5.

3.9.4 **Epoxy mortar.** Ceramic tile set and grouted with chemical-resistant epoxy shall comply with ANSI A118.3. Tile set and grouted with epoxy shall be installed in accordance with ANSI A108.6.

3.9.5 **Furan mortar and grout.** Chemical-resistant furan mortar and grout that are used to install ceramic tile shall comply with ANSI A118.5. Tile set and grouted with furan shall be installed in accordance with ANSI A108.8.

3.9.6 **Modified epoxy-emulsion mortar and grout.** Modified epoxy-emulsion mortar and grout that are used to install ceramic tile shall comply with ANSI A118.8. Tile set and grouted with modified epoxy-emulsion mortar and grout shall be installed in accordance with ANSI A108.9.

3.9.7 **Organic adhesives.** Water-resistant organic adhesives used for the installation of ceramic tile shall comply with ANSI A136.1. The shear bond strength after water immersion shall not be less than 275 kPa for Type I adhesive, and not less than 140 kPa for Type II adhesive, when tested in accordance with ANSI A136.1. Tile set in organic adhesives shall be installed in accordance with ANSI A108.4.

3.9.8 **Portland cement grouts.** Portland cement grouts used for the installation of ceramic tile shall comply with ANSI A118.6. Portland cement grouts for tile work shall be installed in accordance with ANSI A108.10.

SECTION 3.10
GROUT

3.10.0 Grout shall conform to Table 3.10.1 or to ASTM C 476. When grout conforms to ASTM C 476, the grout shall be specified by proportion requirements or property requirements.

TABLE 3.10.1
GROUT PROPORTIONS BY VOLUME FOR MASONRY CONSTRUCTION

TYPE	PARTS BY VOLUME OF PORTLAND CEMENT OR BLENDED CEMENT	PARTS BY VOLUME OF HYDRATED LIME OR LIME PUTTY	AGGREGATE, MEASURED IN A DAMP, LOOSE CONDITION	
			Fine	Coarse
Fine grout	1	$0\text{-}^{1}/_{10}$	2¼-3 times the sum of the volumes of the cementitious materials	–
Coarse grout	1	$0\text{-}^{1}/_{10}$	2¼-3 times the sum of the volumes of the cementitious materials	1-2 times the sum of the volumes of the cementitious materials

SECTION 3.11
METAL REINFORCEMENT AND ACCESSORIES

3.11.0 Metal reinforcement and accessories shall conform to Section 3.11.1 through Section 3.11.6 in conjunction with SBC 304 Appendix F.

3.11.1 **Deformed reinforcing bars.** Deformed reinforcing bars shall conform to one of the following standards: ASTM A 615 for deformed and plain billet-steel bars for concrete reinforcement; ASTM A 706 for low-alloy steel deformed bars for concrete reinforcement; ASTM A 767 for zinc-coated reinforcing steel bars; ASTM A 775 for epoxy-coated reinforcing steel bars and ASTM A 996 for rail steel and axle steel deformed bars for concrete reinforcement.

3.11.2 **Joint reinforcement.** Joint reinforcement shall comply with ASTM A 951. The maximum spacing of cross-wires in ladder-type joint reinforcement and of point of connection of cross wires to longitudinal wires of truss-type reinforcement shall be 400 mm.

3.11.3 **Deformed reinforcing wire.** Deformed reinforcing wire shall conform to ASTM A 496.

3.11.4 **Wire fabric.** Wire fabric shall conform to ASTM A 185 for plain steel-welded wire fabric for concrete reinforcement or ASTM A 496 for welded deformed steel wire fabric for concrete reinforcement.

3.11.5 **Anchors, ties and accessories.** Anchors, ties and accessories shall conform to the following standards: ASTM A 36 for structural steel; ASTM A 82 for plain steel wire for concrete reinforcement; ASTM A 185 for plain steel-welded wire fabric for concrete reinforcement; ASTM A 167, Type 304, for stainless and heat-resisting chromium-nickel steel plate, sheet and strip and ASTM A 366 for cold-rolled carbon steel sheet, commercial quality.

3.11.6 **Corrosion protection.** Corrosion protection for carbon steel accessories used in exterior wall construction or interior walls exposed to a mean relative humidity exceeding 75% shall comply with either Section 3.11.7.1 or Section 3.11.7.2. Corrosion protection for carbon steel accessories used in interior walls exposed to a mean relative humidity equal to or less than 75% shall comply with either Section 3.11.7.1, 3.11.7.2 or Section 3.11.7.3.

3.11.6.1 **Hot-dipped galvanized.** Apply a hot-dipped galvanized coating after fabrication as follows:

1. For joint reinforcement, wall ties, anchors and inserts, apply a minimum coating of 460 g/m^2 complying with the requirements of ASTM A 153, Class B.
2. For sheet metal ties and sheet metal anchors, comply with the requirements of ASTM A 153, Class B.
3. For steel plates and bars, comply with the requirements of either ASTM A 123 or ASTM A 153, Class B.

3.11.6.2 **Epoxy coatings.** Carbon steel accessories shall be epoxy coated as follows:

1. For joint reinforcement, comply with the requirements of ASTM A 884 Class B, Type 2 – 460 µm .

2. For wire ties and anchors, comply with the requirements of ASTM A 899 Class C – 510 μm .

3. For sheet metal ties and anchors, provide a minimum thickness of 510 μm or in accordance with the manufacturer's specification.

3.11.6.3 **Mill galvanized.** Apply a mill galvanized coating as follows:

1. For joint reinforcement, wall ties, anchors and inserts, apply a minimum coating of 30 g/m^2 complying with the requirements of ASTM A 641.

2. For sheet metal ties and sheet metal anchors, apply a minimum coating complying with Coating Designation G-60 according to the requirements of ASTM A 653.

3. For anchor bolts, steel plates or bars not exposed to the earth, weather or a mean relative humidity exceeding 75 percent, a coating is not required.

3.11.7 **Tests.** Where unidentified reinforcement is approved for use, not less than three tension and three bending tests shall be made on representative specimens of the reinforcement from each shipment and grade of reinforcing steel proposed for use in the work.

SECTION 3.12
MATERIAL PROPERTIES

3.12.1 **General.** Unless otherwise determined by test, the following moduli and coefficients shall be used in determining the effects of elasticity, temperature, moisture expansion, shrinkage, and creep.

3.12.2 **Elastic moduli**

Steel reinforcement

$$E_s = 200{,}000 \text{ MPa} \qquad \textbf{Eq. (3-1)}$$

Clay and concrete masonry

The design of clay and concrete masonry shall be based on the following moduli of elasticity values:

$$E_m = 700\, f'_m \text{ for clay masonry;} \qquad \textbf{Eq. (3-2)}$$

$$E_m = 900\, f'_m \text{ for concrete masonry;} \qquad \textbf{Eq. (3-3)}$$

or the chord modulus of elasticity taken between 0.05 and 0.33 of the maximum compressive strength of each prism determined by test in accordance with the prism test method, (Article 1.4 B.3 of AC1 530.1/ASCE 6/TMS 602, and ASTM E 111.)

$$E_v = 0.4\, E_m \qquad \textbf{Eq. (3-4)}$$

Grout — Modulus of elasticity of grout shall be determined by the expression $500\, f'_g$.

3.12.3 **Thermal expansion coefficients**

Clay masonry

$$k_t = 7.2 \times 10^{-6} \text{ mm/mm/°C} \qquad \textbf{Eq. (3-5)}$$

Concrete masonry

$k_t = 8.1 \times 10^{-6}$ mm/mm/°C **Eq.(3-6)**

3.12.4 Moisture expansion coefficients of clay masonry

$k_e = 3 \times 10^{-4}$ mm/mm **Eq. (3-7)**

3.12.5 Shrinkage coefficients of concrete masonry

Masonry made of moisture-controlled concrete masonry units:

$k_m = 0.15\ S_l$ **Eq. (3-8)**

where S_l is not more than 6.5 mm x 10^{-4} mm/mm.

Masonry made of non-moisture-controlled concrete masonry units:

$k_m = 0.5\ S_l$ **Eq. (3-9)**

3.12.6 Creep coefficients

Clay masonry

$k_c = 0.1 \times 10^{-4}$, per MPa **Eq. (3-10)**

Concrete masonry

$k_c = 0.36 \times 10^{-4}$, per MPa **Eq. (3-11)**

SECTION 3.13
SECTION PROPERTIES

3.13.1 Stress computations

3.13.1.1 Member design shall be computed using section properties based on the minimum net cross-sectional area of the member under consideration. Section properties shall be based on specified dimensions.

3.13.1.2 In members designed for composite action, stresses shall be computed using section properties based on the minimum transformed net cross-sectional area concept for elastic analysis, in which areas of dissimilar materials are transformed in accordance with relative elastic moduli ratios shall apply. Actual stresses shall be used to verify compliance with allowable stress requirements.

3.13.2 Stiffness. Determination of stiffness based on uncracked section is permissible. Use of the average net cross-sectional area of the member considered in stiffness computations is permitted.

3.13.3 Radius of gyration. Radius of gyration shall be computed using average net cross-sectional area of the member considered.

3.13.4 Intersecting walls

3.13.4.1 Wall intersections shall meet one of the following requirements:

(a) Design shall conform to the provisions of Section 3.13.4.2.

(b) Transfer of shear between walls shall be prevented.

3.13.4.2 Design of wall intersection

3.13.4.2.1 Masonry shall be in running bond.

3.13.4.2.2 Flanges shall be considered effective in resisting applied loads.

3.13.4.2.3 The width of flange considered effective on each side of the web shall be the lesser of 6 times the flange thickness or the actual flange on either side of the web wall.

3.13.4.2.4 Design for shear, including the transfer of shear at interfaces, shall conform to the requirements of Section 7.2.5 or 7.3.5.

3.13.4.2.5 The connection of intersecting walls shall conform to one of the following requirements:

(a) Fifty percent of the masonry units at the interface shall interlock.

(b) Walls shall be anchored by steel connectors grouted into the wall and meeting the following requirements:

(1) Minimum size: 6.5 mm x 38 mm x 700 mm including 50 mm long 90 degree bend at each end to form a U or Z shape.

(2) Maximum spacing: 1.20 m.

(c) Intersecting bond beams shall be provided in intersecting walls at a maximum spacing of 1.20 m on centers. Bond beams shall be reinforced and the area of reinforcement shall not be less than 200 mm^2/m of wall. Reinforcement shall be developed on each side of the intersections.

CHAPTER 4
CONSTRUCTION

SECTION 4.1
MASONRY CONSTRUCTION

4.1.0 Masonry construction shall comply with the requirements of Section 4.1.1 through Section 4.8.6 and with ACI 530.1/ASCE 6/TMS 602.

4.1.1 **Tolerances.** Masonry, except masonry veneer, shall be constructed within the tolerances specified in ACI 530.1/ASCE 6/TMS 602.

4.1.2 **Placing mortar and units.** Placement of mortar and units shall comply with Sections 4.1.2.1 through 4.1.2.5.

4.1.2.1 **Bed and head joints.** Unless otherwise required or indicated on the construction documents, head and bed joints shall be 10 mm thick, except that the thickness of the bed joint of the starting course placed over foundations shall not be less than 6 mm and not more than 20 mm.

4.1.2.1.1 **Open-end units.** Open-end units with beveled ends shall be fully grouted. Head joints of open-end units with beveled ends need not be mortared. The beveled ends shall form a grout key that permits grouts within 15 mm of the face of the unit. The units shall be tightly butted to prevent leakage of the grout.

4.1.2.2 **Hollow units.** Hollow units shall be placed such that face shells of bed joints are fully mortared. Webs shall be fully mortared in all courses of piers, columns, pilasters, in the starting course on foundations where adjacent cells or cavities are to be grouted, and where otherwise required. Head joints shall be mortared a minimum distance from each face equal to the face shell thickness of the unit.

4.1.2.3 **Solid units.** Unless otherwise required or indicated on the construction documents, solid units shall be placed in fully mortared bed and head joints. The ends of the units shall be completely buttered. Head joints shall not be filled by slushing with mortar. Head joints shall be constructed by shoving mortar tight against the adjoining unit. Bed joints shall not be furrowed deep enough to produce voids.

4.1.2.4 **Glass unit masonry.** Glass units shall be placed so head and bed joints are filled solidly. Mortar shall not be furrowed.

Unless otherwise required, head and bed joints of glass unit masonry shall be 6 mm thick, except that vertical joint thickness of radial panels shall not be less than 3 mm. The bed joint thickness tolerance shall be minus 2 mm and plus 3 mm. The head joint thickness tolerance shall be plus or minus 3 mm.

4.1.2.5 **All units.** Units shall be placed while the mortar is soft and plastic. Any unit disturbed to the extent that the initial bond is broken after initial positioning shall be removed and re-laid in fresh mortar.

4.1.2.6 **Adhered veneer.** Tap the veneer unit into place, completely filling the space between the veneer unit and the backing. Sufficient mortar shall be used to create a slight excess to be forced out between the edges of the veneer units. The resulting thickness of the mortar in back of the veneer unit shall not be less than 10 mm nor more than 30 mm.

4.1.3 **Installation of wall ties.** The ends of wall ties shall be embedded in mortar joints. Wall tie ends shall engage outer face shells of hollow units by at least 12 mm.

Wire wall ties shall be embedded at least 38 mm into the mortar bed of solid masonry units or solid-grouted hollow units. Wall ties shall not be bent after being embedded in grout or mortar.

4.1.4 **Chases and recesses.** Chases and recesses shall be constructed as masonry units are laid. Masonry directly above chases or recesses wider than 300 mm shall be supported on lintels.

4.1.5 **Deflection**

4.1.5.1 **Deflection of beams and lintels.** Deflection of beams and lintels due to dead plus live loads shall not exceed the lesser of 8 mm when providing vertical support to masonry designed in accordance with Chapter 7 or Chapter 8. Minimum length of end support shall be 100 mm.

4.1.5.2 **Connection to structural frames.** Masonry walls shall not be connected to structural frames unless the connections and walls are designed to resist design interconnecting forces and to accommodate calculated deflections.

4.1.6 **Support on wood.** Masonry shall not be supported on wood girders or other forms of wood construction.

4.1.7 **Masonry protection.** The top of unfinished masonry work shall be covered to protect the masonry from the weather.

4.1.8 **Weep holes.** Weep holes provided in the outside wythe of masonry walls shall be at a maximum spacing of 850 mm on center. Weep holes shall not be less than 5 mm in diameter.

4.1.9 **Stack bond masonry**

For masonry in other than running bond, the minimum area of horizontal reinforcement shall be 0.00028 times the gross vertical cross-sectional area of the wall using specified dimensions. Horizontal reinforcement shall be placed in horizontal joints or in bond beams spaced not more than 1200 mm on center.

SECTION 4.2
CORBELED MASONRY

4.2.0 The maximum corbeled projection beyond the face of the wall shall not be more than one-half of the wall thickness nor one-half the wythe thickness for hollow walls. The maximum projection of one unit shall neither exceed one-half the height of the unit nor one-third the thickness at right angles to the wall.

4.2.1 **Molded cornices.** Unless structural support and anchorage are provided to resist the overturning moment, the center of gravity of projecting masonry or molded cornices shall lie within the middle one-third of the supporting wall. Terra cotta and metal cornices shall be provided with a structural frame of approved noncombustible material anchored in an approved manner.

SECTION 4.3
COLD WEATHER CONSTRUCTION

4.3.0 The cold weather construction provisions of ACI 530.1/ASCE 6/TMS 602, Article 1.8 C, or the following procedures shall be implemented when either the ambient temperature falls below 4 °C or the temperature of masonry units is below 4 °C.

4.3.1 **Preparation.**

1. Temperatures of masonry units shall not be less than -7 °C when laid in the masonry. Masonry units containing frozen moisture, visible ice or snow on their surface shall not be laid.
2. Visible ice and snow shall be removed from the top surface of existing foundations and masonry to receive new construction. These surfaces shall be heated to above freezing, using methods that do not result in damage.

4.3.2 **Construction.** The following requirements shall apply to work in progress and shall be based on ambient temperature.

4.3.2.1 **Construction requirements for temperatures between 4 °C and 0 °C.** The following construction requirements shall be met when the ambient temperature is between 4 °C and 0 °C:

1. Glass unit masonry shall not be laid.
2. Water and aggregates used in mortar and grout shall not be heated above 60 °C.
3. Mortar sand or mixing water shall be heated to produce mortar temperatures between 4 °C and 49 °C at the time of mixing. When water and aggregates for grout are below 0 °C, they shall be heated.

4.3.2.2 **Construction requirements for temperatures between 0 °C and -4 °C.** The requirements of Section 4.3.2.1 and the following construction requirements shall be met when the ambient temperature is between 0 °C and -4 °C:

1. The mortar temperature shall be maintained above freezing until used in masonry.
2. Aggregates and mixing water for grout shall be heated to produce grout temperature between 21 °C and 49 °C at the time of mixing. Grout temperature shall be maintained above 21 °C at the time of grout placement.

4.3.2.3 **Construction requirements for temperatures between -4 °C and -7 °C.** The requirements of Section 4.3.2.1 and 4.3.2.2 and the following construction requirements shall be met when the ambient temperature is between -4 °C and -7 °C:

1. Masonry surfaces under construction shall be heated to 4 °C.
2. Wind breaks or enclosures shall be provided when the wind velocity exceeds 24 km/h.
3. Prior to grouting, masonry shall be heated to a minimum of 4 °C.

4.3.2.4 **Construction requirements for temperatures below -7°C.** The requirements of Section 4.3.2.1, 4.3.2.2 and 4.3.2.3 and the following construction requirement shall be met when the ambient temperature is below -7°C. Enclosures and auxiliary heat shall be provided to maintain air temperature within the enclosure to above 0°C.

4.3.3 **Protection.** The requirements of this section and Section 4.3.3.1 through 4.3.3.4 apply after the masonry is placed and shall be based on anticipated minimum daily temperature for grouted masonry and anticipated mean daily temperature for ungrouted masonry.

4.3.3.1 **Glass unit masonry.** The temperature of glass unit masonry shall be maintained above 4°C for 48 hours after construction.

4.3.3.2 **Protection requirements for temperatures between 4°C and -4°C.** When the temperature is between 4°C and -4°C, newly constructed masonry shall be covered with a weather-resistive membrane for 24 hours after being completed.

4.3.3.3 **Protection requirements for temperatures between -4°C and -7°C.** When the temperature is between -4°C and -7°C, newly constructed masonry shall be completely covered with weather-resistive insulating blankets, or equal protection, for 24 hours after being completed. The time period shall be extended to 48 hours for grouted masonry, unless the only cement in the grout is Type III Portland cement.

4.3.3.4 **Protection requirements for temperatures below -7°C.** When the temperature is below -7°C, newly constructed masonry shall be maintained at a temperature above 0°C for at least 24 hours after being completed by using heated enclosures, electric heating blankets, infrared lamps or other acceptable methods. The time period shall be extended to 48 hours for grouted masonry, unless the only cement in the grout is Type III Portland cement.

SECTION 4.4
HOT WEATHER CONSTRUCTION

4.4.0 The hot weather construction provisions of ACI 530.1/ASCE 6/TMS 602, Article 1.8 D, or the following procedures shall be implemented when the temperature or the temperature and wind-velocity limits of this section are exceeded.

4.4.1 **Preparation.** The following requirements shall be met prior to conducting masonry work.

4.4.1.1 **Temperature.** When the ambient temperature exceeds 38°C, or exceeds 32°C with a wind velocity greater than 13 km/h:

1. Necessary conditions and equipment shall be provided to produce mortar having a temperature below 49°C.
2. Sand piles shall be maintained in a damp, loose condition.

4.4.1.2 **Special conditions.** When the ambient temperature exceeds 46°C, or 40°C with a wind velocity greater than 13 km/h, the requirements of Section 4.4.1.1 shall be implemented, and materials and mixing equipment shall be shaded from direct sunlight.

4.4.2 **Construction.** The following requirements shall be met while masonry work is in progress.

4.4.2.1 **Temperature.** When the ambient temperature exceeds 38 ° C, or exceeds 32 ° C with a wind velocity greater than 13 km/h:

1. The temperature of mortar and grout shall be maintained below 49 ° C.
2. Mixers, mortar transport containers and mortar boards shall be flushed with cool water before they come into contact with mortar ingredients or mortar.
3. Mortar consistency shall be maintained by retempering with cool water.
4. Mortar shall be used within 2 hours of initial mixing.

4.4.2.2 **Special conditions.** When the ambient temperature exceeds 46 ° C, or exceeds 40 ° C with a wind velocity greater than 13 km/h, the requirements of Section 4.4.2.1 shall be implemented and cool mixing water shall be used for mortar and grout. The use of ice shall be permitted in the mixing water prior to use. Ice shall not be permitted in the mixing water when added to the other mortar or grout materials.

4.4.3 **Protection.** When the mean daily temperature exceeds 38 ° C, or exceeds 32 ° C with a wind velocity greater than 13 km/h, newly constructed masonry shall be fog sprayed until damp at least three times a day until the masonry is three days old.

SECTION 4.5
WETTING OF BRICK

4.5.0 Brick (clay or shale) at the time of laying shall require wetting if the unit's initial rate of water absorption exceeds 30 grams per 20,000 mm^2 per minute or 1 g/645 mm^2, as determined by ASTM C 67.

SECTION 4.6
GROUTING, MINIMUM SPACES

4.6.0 The minimum dimensions of spaces provided for the placement of grout shall be in accordance with Table 4.6.1. Higher group pours, higher grout lifts, smaller cavity widths, or smaller cell sizes than those shown in Table 4.6.1 are permitted if the results of a grout demonstration panel show that the grout spaces are filled and adequately consolidated. In that case, the procedures used in constructing the grout demonstration panel shall be the minimum acceptable standard for grouting, and the quality assurance program shall include inspection during construction to verify grout placement.

SECTION 4.7
EMBEDDED CONDUITS, PIPES, AND SLEEVES

4.7.0 Conduits pipes and sleeves of any material to be embedded in masonry shall be compatible with masonry and shall comply with the following requirements.

4.7.1 Design shall not consider conduits, pipes, or sleeves as structurally replacing the displaced masonry.

4.7.2 Design shall consider the structural effects resulting from the removal of masonry to allow for the placement of pipes or conduits.

4.7.3 Conduits, pipes, and sleeves in masonry shall be no closer than 3 diameters on center.

4.7.4 Maximum area of vertical conduits, pipes, or sleeves placed in masonry columns or pilasters shall not displace more than 2% of the net cross section.

4.7.5 Pipes shall not be embedded in masonry when:

(a) Containing liquid, gas, or vapors at temperature higher than 66 °C.

(b) Under pressure in excess of 380 kPa.

(c) Containing water or other liquids subject to freezing.

TABLE 4.6.1
Grout Space Requirements

Grout type[1]	Maximum grout pour height, m	Minimum width of grout space, [2,3] mm	Minimum grout space dimensions for grouting cells of hollow units, [3,4] mm x mm
Fine	0.3	20	38 x 51
Fine	1.5	50	50 x 76
Fine	3.7	60	63 x 76
Fine	7.3	75	76 x 76
Coarse	0.3	38	38 x 76
Coarse	1.5	50	63 x 76
Coarse	3.7	60	76 x 76
Coarse	7.3	75	76 x 102

1 Fine and coarse grouts are defined in ASTM C 476.
2 For grouting between masonry wythes.
3 Grout space dimension is the clear dimension between any masonry protrusion and shall be increased by the diameters of the horizontal bars within the cross section of the grout space.
4 Area of vertical reinforcement shall not exceed 6 percent of the area of the grout space.

SECTION 4.8
REINFORCEMENT

4.8.1 Embedment

Reinforcing bars shall be embedded in grout.

4.8.2 Size of reinforcement

4.8.2.1 The maximum size of reinforcement used in masonry shall be (Dia 36).

4.8.2.2 The diameter of reinforcement shall not exceed one-half the least clear dimension of the cell, bond beam, or collar joint in which it is placed.

4.8.2.3 Longitudinal and cross wires of joint reinforcement shall have a minimum wire size of (WD 4) and a maximum wire size of one half the joint thickness.

4.8.3 Placement of reinforcement

4.8.3.1 The clear distance between parallel bars shall not be less than the nominal diameter of the bars, nor less than 25 mm.

4.8.3.2 In columns and pilasters, the clear distance between vertical bars shall not be less than one and one-half times the nominal bar diameter, nor less than 40 mm.

4.8.3.3 The clear distance limitations between bars required in Section 4.8.3.1 and 4.8.3.2 shall also apply to the clear distance between a contact lap splice and adjacent splices or bars.

4.8.3.4 Groups of parallel reinforcing bars bundled in contact to act as a unit shall be limited to two in any one bundle. Individual bars in a bundle cut off within the span of a member shall terminate at points at least 40 bar diameters apart.

4.8.3.5 Reinforcement embedded in grout shall have a thickness of grout between the reinforcement and masonry units not less than 6 mm for fine grout or 13 mm for coarse grout.

4.8.4 Protection of reinforcement

4.8.4.1 Reinforcing bars shall have a masonry cover not less than the following:

- **(a)** Masonry face exposed to earth or weather: 50 mm for bars larger than (Dia 16); 40 mm for (Dia 16) bars or smaller.
- **(b)** Masonry not exposed to earth or weather: 40 mm.

4.8.4.2 Longitudinal wires of joint reinforcement shall be fully embedded in mortar or grout with a minimum cover of 16 mm when exposed to earth or weather and 13 mm when not exposed to earth or weather. Joint reinforcement shall be stainless steel or protected from corrosion by hot-dipped galvanized coating or epoxy coating when used in masonry exposed to earth or weather and in interior walls exposed to a mean relative humidity exceeding 75%. All other joint reinforcement shall be mill galvanized, hot-dip galvanized, or stainless steel.

4.8.4.3 Wall ties, sheet metal anchors, steel plates and bars, and inserts exposed to earth or weather, or exposed to a mean relative humidity exceeding 75% shall be stainless steel or protected from corrosion by hot-dip galvanized coating or epoxy coating. Wall ties, anchors, and inserts shall be mill galvanized, hot-dip galvanized, or stainless steel for all other cases. Anchor bolts, steel plates, and bars not exposed to earth, weather, nor exposed to a mean relative humidity exceeding 75%, need not be coated.

4.8.5 Standard hooks

- **(a)** A 180 degree turn plus extension of at least 4 bar diameters but not less than 64 mm at free end of bar.
- **(b)** A 90 degree turn plus extension of at least 12 bar diameters at free end of bar.
- **(c)** For stirrup and tie anchorage only, either a 90 degree or a 135 degree turn plus an extension of at least 6 bar diameters at the free end of the bar.

4.8.6 Minimum bend diameter for reinforcing bars

The diameter of bend measured on the inside of reinforcing bars, other than for stirrups and ties, shall not be less than values specified in Table 4.8.1.

Table 4.8.1
Minimum diameters of bend

Bar size and type	Minimum diameter
(Dia 10) through (Dia 22) Grade 300	5 bar diameters
(Dia 10) through (Dia 25) Grade 350 or 420	6 bar diameters
(Dia 28), (Dia 32), and (Dia 36) Grade 350 or 420	8 bar diameters

CHAPTER 5
QUALITY ASSURANCE

SECTION 5.1
GENERAL

5.1.0 A quality assurance program shall be used to ensure that the constructed masonry is in compliance with the construction documents.

The minimum quality assurance program shall comply with the requirements of this chapter and Table 5.1.1. The quality assurance program shall itemize the methods used to verify conformance of material composition, quality, storage, handling, preparation, and placement with the requirements of ACI 530.1/ASCE 6/TMS 602.

5.1.1 The quality assurance program shall define the qualifications for testing laboratories and for inspection agencies and shall comply with the inspection and testing requirements of SBC 302.

TABLE 5.1.1
QUALITY ASSURANCE

MINIMUM TESTS AND SUBMITTALS	MINIMUM INSPECTION
Certificates for materials used in masonry construction indicating compliance with the contract documents. Verification of f_m' • Prior to construction • Every 500 m^2 during construction Verification of proportions of materials in mortar and grout as delivered to the site.	From the beginning of masonry construction and continuously during construction of masonry, verify the following are in compliance: • proportions of site-mixed mortar, grout, and prestressing grout for bonded tendons • grade and size of reinforcement, prestressing tendons and anchorages • placement of masonry units and construction of mortar joints • placement of reinforcement, connectors, and prestressing tendons and anchorages • grout space prior to grouting • placement of grout and prestressing grout for bonded tendons Observe preparation of grout specimens, mortars specimens, and/or prisms. Verify compliance with the required inspection provisions of the contract documents and the approved submittals.

SECTION 5.2
ACCEPTANCE RELATIVE TO STRENGTH REQUIREMENTS

5.2.1 **Compliance with f_m'.** Compressive strength of masonry shall be considered satisfactory if the compressive strength of each masonry wythe and grouted collar joint equals or exceeds the value of f_m'.

5.2.2 **Determination of compressive strength.** The compressive strength for each wythe shall be determined by the unit strength method or by the prism test method as specified herein.

5.2.2.1 **Unit strength method.**

5.2.2.1.1 **Clay masonry.** The compressive strength of masonry shall be determined based on the strength of the units and the type of mortar specified using Table 5.2.1, provided:

1. Units conform to ASTM C 62, ASTM C 216 or ASTM C 652 and are sampled and tested in accordance with ASTM C 67.
2. Thickness of bed joints does not exceed 16 mm.
3. For grouted masonry, the grout meets one of the following requirements:
   a. Grout conforms to ASTM C 476.
   b. Minimum grout compressive strength equals $f_m^{'}$ but not less than 14 MPa. The compressive strength of grout shall be determined in accordance with ASTM C 1019.

TABLE 5.2.1
COMPRESSIVE STRENGTH OF CLAY MASONRY

NET AREA COMPRESSIVE STRENGTH OF CLAY MASONRY UNITS (MPa)		NET AREA COMPRESSIVE STRENGTH OF MASONRY (MPa)
Type M or S mortar	Type N mortar	
12	14.5	7
23	29	10.5
34	43	14
46	57	17.5
57	71	21
68	–	24.5
91	–	28

5.2.2.1.2 **Concrete masonry.** The compressive strength of masonry shall be determined based on the strength of the unit and type of mortar specified using Table 5.2.2, provided:

1. Units conform to ASTM C 55, ASTM C 90 and are sampled and tested in accordance with ASTM C 140.
2. Thickness of bed joints does not exceed 16 mm.
3. For grouted masonry, the grout meets one of the following requirements:
   a. Grout conforms to ASTM C 476.
   b. Minimum grout compressive strength equals $f_m^{'}$ but not less than 14 MPa. The compressive strength of grout shall be determined in accordance with ASTM C 1019.

5.2.2.2 **Prism test method.**

5.2.2.2.1 **General.** The compressive strength of masonry shall be determined by the prism test method:

1. Where specified in the construction documents.
2. Where masonry does not meet the requirements for application of the unit strength method in Section 5.2.2.1.

5.2.2.2.2 **Number of prisms per test.** A prism test shall consist of three prisms constructed and tested in accordance with ASTM C 1314.

TABLE 5.2.2
COMPRESSIVE STRENGTH OF CONCRETE MASONRY

NET AREA COMPRESSIVE STRENGTH OF CLAY MASONRY UNITS (MPa)		NET AREA COMPRESSIVE STRENGTH OF MASONRY (MPa)[a]
Type M or S mortar	Type N mortar	
9	9	7
13	15	10.5
19	21	14
26	28	17.5
33	36	21

a. For units of less than 100 mm in height, 85 percent of the values listed.

SECTION 5.3
TESTING PRISMS FROM CONSTRUCTED MASONRY

5.3.0 When approved by the building official, acceptance of masonry that does not meet the requirements of Section 5.2.2.1 or 5.2.2.2 shall be permitted to be based on tests of prisms cut from the masonry construction in accordance with Section 5.3.1, 5.3.2 and 5.3.3.

5.3.1 **Prism sampling and removal.** A set of three masonry prisms that are at least 28 days old shall be saw cut from the masonry for each 500 m^2 of the wall area that is in question but not less than one set of three masonry prisms for the project. The length, width and height dimensions of the prisms shall comply with the requirements of ASTM C 1314. Transporting, preparation and testing of prisms shall be in accordance with ASTM C 1314.

5.3.2 **Compressive strength calculations.** The compressive strength of prisms shall be the value calculated in accordance ASTM C 1314, except that the net cross-sectional area of the prism shall be based on the net mortar bedded area.

5.3.3 **Compliance.** Compliance with the requirement for the specified compressive strength of masonry, f_m' shall be considered satisfied provided the modified compressive strength equals or exceeds the specified f_m'. Additional testing of specimens cut from locations in question shall be permitted.

CHAPTER 6
SEISMIC DESIGN

SECTION 6.1
SEISMIC DESIGN REQUIREMENTS FOR MASONRY

6.1.0 Masonry structures and components shall comply with the requirements in Section 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.5 depending on the structure's seismic design category as determined in SBC 301. All masonry walls, unless isolated on three edges from in-plane motion of the basic structures systems, shall be considered to be part of the seismic-force-resisting system.

6.1.1 **Basic seismic-force-resisting system –** Buildings relying on masonry shear walls as part of the Basic seismic-force-resisting system shall have shear walls that comply with the requirements of Sections 6.1.1.1, 6.1.1.2, 6.1.1.3, 6.1.1.4 and 6.1.1.5.

Exception: Buildings assigned to Seismic Design Category A shall be permitted to have shear walls complying with Section 9.2.

6.1.1.1 **Ordinary plain (unreinforced) masonry shear walls** – Design of ordinary plain (unreinforced) masonry shear walls shall comply with the requirements of Section 7.2 and 8.3.

6.1.1.2 **Detailed plain (unreinforced) masonry shear walls** – Design of detailed plain (unreinforced) masonry shear walls shall comply with the requirements of Section 7.2 or 8.3, and shall comply with the requirements of Section 6.1.1.2.1 and 6.1.1.2.2.

6.1.1.2.1 **Minimum reinforcement requirements** – Vertical reinforcement of at least 130 mm^2 in cross-sectional area shall be provided at corners, within 400 mm of each side of openings, within 200 mm of each side of movement joints, within 200 mm of the ends of walls, and at a maximum spacing of 3.0 m on center.

Reinforcement adjacent to openings need not be provided for opening smaller than 400 mm in either the horizontal or vertical direction, unless the spacing of distributed reinforcement is interrupted by such openings.

Horizontal joint reinforcement shall consist of at least two wires of WD 4 spaced not more than 400 mm; or bond beam reinforcement shall be provided of at least 130 mm^2 in cross-sectional area spaced not more than 3.0 m. Horizontal reinforcement shall also be provided at the bottom and top of wall openings and shall extend not less than 600 mm nor less than 40 bar diameters past the opening; continuously at structurally connected roof and floor levels; and within 400 mm of the top of walls.

6.1.1.2.2 **Connections** – Connectors shall be provided to transfer forces between masonry walls and horizontal elements in accordance with the requirements of Section 7.1.8. Connectors shall be designed to transfer horizontal design forces acting either perpendicular or parallel to the wall, but not less than 3000 N per lineal m of wall. The maximum spacing between connectors shall be 1.20 m.

6.1.1.3 **Ordinary reinforced masonry shear walls** – Design of ordinary reinforced masonry shear walls shall comply with the requirements of reinforced Masonry in Section 7.3 or 8.2, and shall comply with the requirements of Section 6.1.1.2.1 and 6.1.1.2.2.

6.1.1.4 **Intermediate reinforced masonry shear walls** – Design of intermediate reinforced masonry shear walls shall comply with the requirements of reinforced Masonry in Section 7.3 or 8.2. Design shall also comply with the requirements of Section 6.1.1.2.1 and 6.1.1.2.2, except that the spacing of vertical reinforcement in intermediate reinforced masonry shear walls shall not exceed 1200 mm.

6.1.1.5 **Special reinforced masonry shear walls** – Design of special reinforced masonry shear walls shall comply with the requirements of reinforced Masonry in Section 7.3 or 8.2. Design shall also comply with the requirements of Sections 6.1.1.2.1, 6.1.1.2.2, 6.1.5.3, and the following:

(a) The maximum spacing of vertical and horizontal reinforcement shall be the smaller of; one-third the length of the shear wall; one-third the height of the shear wall; or 1200 mm.

(b) The minimum cross-sectional area of vertical reinforcement shall be one-third of the required shear reinforcement.

(c) Shear reinforcement shall be anchored around vertical reinforcing bars with a standard hook.

6.1.2 Seismic Design Category A

6.1.2.1 Structure in Seismic design category A shall comply with the requirements of Chapter 7, Chapter 8 or Chapter 9.

6.1.2.2 **Drifts limits –** The calculated story drift of masonry structures due to the combination of design seismic forces and gravity loads shall not exceed 0.007 times the story height.

6.1.3 Seismic Design Category B

6.1.3.1 Structures in Seismic Design category B shall comply with the requirements of Seismic design Category A and to the additional requirements in Section 6.1.3.2 and 6.1.3.3.

6.1.3.2 **Design of elements that are part of basic seismic-force-resisting system.** The lateral force-resisting system shall be designed to comply with the requirements of Chapter 7, Chapter 8 and Chapter 9. Masonry shear walls shall comply with the requirements of ordinary plain (unreinforced) masonry shear walls, detailed plain (unreinforced) masonry shear walls, ordinary reinforced masonry shear walls, intermediate reinforced masonry shear walls, or special reinforced masonry shear walls.

6.1.3.3 **Masonry walls not part of the basic seismic-force-resisting system**. Masonry partition walls, masonry screen walls and other masonry elements that are not designed to resist vertical or lateral loads, other than those induced by their own mass. Shall be isolated from the structure so that the vertical and lateral forces are not imparted to these elements. Isolation joints and connectors between these elements and the structure shall be designed to accommodate the design story drift.

6.1.4 Seismic Design Category C

6.1.4.1 Structures in Seismic Design Category C shall comply with the requirements of Seismic Design Category B and to the additional requirements in Section 6.1.4.2 and 6.1.4.3.

6.1.4.2 Design of elements that are not part of basic seismic-force-resisting system

6.1.4.2.1 Load-bearing frames or columns that are not part of the lateral force-resisting system shall be analyzed as to their effect on the response of the system. Such frames or columns shall be adequate for vertical load carrying capacity and induced moment due to the design story drift.

6.1.4.2.2 Masonry partition walls, masonry screen walls and other masonry elements that are not designed to resist vertical or lateral loads, other than those induced by their own mass, shall be isolated from the structure so that vertical and lateral forces are not imparted to these elements. Isolation joints and connectors between these elements and the structure shall be designed to accommodate the design story drift.

6.1.4.2.3 **Reinforcement requirements.** Masonry elements listed in Section 6.1.4.2.2 shall be reinforced in either the horizontal or vertical direction in accordance with the following:

(a) Horizontal reinforcement. Horizontal joint reinforcement shall consist of at least two longitudinal WD 4 wires spaced not more than 400 mm for walls greater than 100 mm in width and at least one longitudinal WD 4 wire spaced not more 400 mm for walls not exceeding 100 mm in width; or at least one (Dia 12) bar spaced not more than 1200 mm. Where two longitudinal wires of joint reinforcement are used, the space between these wires shall be the widest that the mortar joint will accommodate. Horizontal reinforcement shall be provided within 400 mm of the top and bottom of these masonry walls.

(b) Vertical reinforcement. Vertical reinforcement shall consist of at least one (Dia 12) bar spaced not more than 1200 mm. Vertical reinforcement shall be located within 400 mm of the ends of masonry walls.

6.1.4.3 Design of elements that are part of the Basic seismic-force-resisting system

6.1.4.3.1 **Connections to masonry columns.** Connectors shall be provided to transfer forces between masonry columns and horizontal elements in accordance with the requirements of Section 7.1.8. Where anchor bolts are used to connect horizontal elements to the tops of columns, anchor bolts shall be placed within lateral ties. Lateral ties shall enclose both the vertical bars in the column and the anchor bolts. There shall be a minimum of two (Dia 12) lateral ties provided in the top 130 mm of the column.

6.1.4.3.2 **Masonry shear walls.** Masonry shear walls shall comply with the requirements for ordinary reinforced masonry shear walls, intermediate reinforced masonry shear walls, or special reinforced masonry shear walls.

6.1.4.4 **Design of discontinuous members that are part of the lateral-force-resisting system.** Columns and pilasters that are part of the lateral-force-resisting system and that support reactions from discontinuous stiff members such as walls shall be provided with transverse reinforcement spaced at no more than one-fourth of the least nominal dimension of the column or pilaster. The minimum transverse reinforcement ratio shall be 0.0015. Beams supporting reactions from discontinuous walls or frames shall be provided with transverse reinforcement spaced at no more than one-half of the nominal depth of the beam. The minimum transverse reinforcement ratio shall be 0.0015.

6.1.5 Seismic design category D

6.1.5.1 Structures in Seismic design Category D shall comply with the requirements of Seismic Design Category C and to the additional requirements in Section 6.1.5.2 to 6.1.5.9.

6.1.5.2 **Design requirements** – Masonry elements, other than those covered by Section 6.1.4.2.2, shall be designed in accordance with the requirements of Sections 7.1 and 7.3 or Chapter 8.

6.1.5.3 **Minimum reinforcement requirements for masonry walls** – Masonry walls other than those covered by section 6.1.4.2.3 shall be reinforced in both the vertical and horizontal direction. The sum of the cross-sectional area of horizontal and vertical reinforcement shall be at least 0.002 times the gross cross-sectional area of the wall, and the minimum cross-sectional area in each direction shall be not less than 0.0007 times the gross cross-sectional area of the wall, using specified dimensions. Reinforcement shall be uniformly distributed. The maximum spacing of reinforcement shall be 1200 mm except for stack bond masonry. Wythes of stack bond masonry shall be constructed of fully grouted hollow open-end units, fully grouted hollow units laid with full head joints or solid units. Maximum spacing of reinforcement for walls with stack bond masonry shall be 600 mm.

6.1.5.4 **Masonry shear walls** – Masonry shear walls shall comply with the requirements for special reinforced masonry shear walls.

6.1.5.5 **Minimum reinforcement for masonry columns** – Lateral ties in masonry columns shall be spaced not more than 200 mm on center and shall be at least 10 mm diameter. Lateral ties shall be embedded in grout.

6.1.5.6 **Material requirements** – Neither Type N mortar nor masonry cement shall be used as part of the lateral force-resisting system.

6.1.5.7 **Lateral tie anchorage** – Standard hooks for lateral tie anchorage shall be either a 135 degree standard hook or a 180 degree standard hook.

6.1.5.8 **Loads for shear walls designed by the working stress design method** – When calculating shear or diagonal tension stresses by the working stress design method. Shear walls that resist seismic forces shall be designed to resist 1.5 times the forces required by SBC 301. The multiplier need not be applied to the overturning moment.

6.1.5.9 **Shear walls shear strength** – For all shear walls whose nominal shear strength exceeds the shear corresponding to development of its nominal flexural strength, two shear regions exist.

For all cross sections within a region defined by the base of the shear wall and a plane at a distance L_w above the base of the shear wall, the nominal shear strength shall be determined by Equation (6-1).

$$V_n = A_n \rho_n f_y \qquad \textbf{Eq. (6-1)}$$

The required shear strength for this region shall be calculated at a distance $L_w/2$ above the base of the shear wall, but not to exceed one-half story height.

For the other region, the nominal shear strength of the shear wall shall be determined from Chapter 8.

SECTION 6.2
ANCHORAGE OF MASONRY WALLS

6.2.1 Masonry walls shall be anchored to the roof and floors that provide lateral support for the wall in accordance with Section 10.11 SBC 301.

CHAPTER 7
WORKING STRESS DESIGN

SECTION 7.1
GENERAL

7.1.1 **Scope.** This chapter provides minimum requirements for allowable stress design of masonry. Masonry designed by working stress design method shall comply with the requirements of Section 7.1 and either Section 7.2 or Section 7.3.

7.1.2 **Load combinations:** Loads and Load Combinations are in accordance with SBC 301. The allowable stresses and allowable loads are permitted to be increased by one third when considering load combinations of Section 2.4, SBC 301.

7.1.3 **Design strength**

7.1.3.1 Project drawings shall show the specified compressive strength of masonry, $f_m^{'}$, for each part of the structure.

7.1.3.2 Each portion of the structure shall be designed based on the specified compressive strength of masonry, $f_m^{'}$, for that part of the work.

7.1.4 **Anchor bolts solidly grouted in masonry**

7.1.4.1 **Test design requirements** – Except as provided in Section 7.1.4.2, anchor bolts shall be designed based on the following provisions.

7.1.4.1.1 Anchors shall be tested in accordance with ASTM E 488 under stresses and conditions representing intended use, except that a minimum of five tests shall be performed.

7.1.4.1.2 Allowable loads shall not exceed 20% of the average tested strength.

7.1.4.2 **Plate, headed, and bent bar anchor bolts** – The allowable loads for plate anchors, headed anchor bolts, and bent bar anchor bolts (J or L type) embedded in masonry shall be determined in accordance with the provisions of Section 7.1.4.2.1 through Section 7.1.4.2.4.

7.1.4.2.1 The minimum effective embedment length shall be 4 bolt diameters, but not less than 50 mm.

7.1.4.2.2 The allowable load in tension shall be the lesser of that given by Eq. (7-1) or Eq. (7-2).

$$B_a = 0.042\, A_p \sqrt{f'_m} \qquad \textbf{Eq. (7-1)}$$

$$B_a = 0.2\, A_b f_y \qquad \textbf{Eq. (7-2)}$$

7.1.4.2.2.1 The area A_p shall be the lesser of Eq. (7-3) or Eq. (7-4). Where the projected areas of adjacent anchor bolts overlap, A_p of each bolt shall be reduced by on-half of the overlapping area. That portion of the projected area falling in an open cell or core shall be deducted from the value of A_p calculated using Eq. (7-3) or (7-4).

$$A_p = \pi\, l_b^2 \qquad \textbf{Eq. (7-3)}$$

$$A_p = \pi\, l_{be}^2 \qquad \textbf{Eq. (7-4)}$$

7.1.4.2.2.2 The effective embedment length of plate or headed bolts, l_b, shall be the length of embedment measured perpendicular from the surface of the masonry to the bearing surface of the plate or head of the anchor bolt.

7.1.4.2.2.3 The effective embedment length of bent anchors, l_b, shall be the length of embedment measured perpendicular from the surface of the masonry to the bearing surface of the bent end minus one anchor bolt diameter.

7.1.4.2.3 The allowable load in shear, where l_{be} equals or exceeds 12 bolt diameters, shall be the lesser of that given by Eq. (7-5) or Eq. (7-6).

$$B_v = 1072\sqrt[4]{f'_m\ A_b} \qquad \textbf{Eq. (7-5)}$$

$$B_v = 0.12\,A_b f_y \qquad \textbf{Eq. (7-6)}$$

Where l_{be} is less than 12 bolt diameters, the value of B_v in Eq. (7-5) shall be reduced by linear interpolation to zero at an l_{be} distance of 25 mm.

7.1.4.2.4 **Combined shear and tension** – Anchors in Section 7.1.4.2 subjected to combined shear and tension shall be designed to satisfy Eq. (7-7).

$$\frac{b_a}{B_a} + \frac{b_v}{B_v} \leq 1 \qquad \textbf{Eq. (7-7)}$$

7.1.5 Multiwythe walls

7.1.5.1 Design of walls composed of more than one wythe shall comply with the provisions of Section 7.1.5.

7.1.5.2 Composite action

7.1.5.2.1 Multiwythe walls designed for composite action shall have collar joints either:

(a) crossed by connecting headers, or

(b) filled with mortar or grout and connected by wall ties.

7.1.5.2.2 Shear stresses developed in the planes of interfaces between wythes and collar joints or within headers shall not exceed the following:

(a) mortared collar joints, 35 kPa.

(b) grouted collar joints, 70 kPa.

(c) headers, square root of unit compressive strength of header, MPa (over net area of header).

7.1.5.2.3 Headers of wythes bonded by headers shall meet the requirements of Section 7.1.5.2.2 and shall be provided as follows:

(a) Headers shall be uniformly distributed and the sum of their cross-sectional areas shall be at least 4% of the wall surface area.

(b) Headers connecting adjacent wythes shall be embedded a minimum of 80 mm in each wythe.

7.1.5.2.4 Wythes not bonded by headers shall meet the requirements of Section 7.1.5.2.2 and shall be bonded by wall ties provided as follows:

Wire size	Minimum number of wall ties required
WD 4	one per 0.25 m^2 of wall
WD 5	one per 0.40 m^2 of wall

The maximum spacing between ties shall be 900 mm horizontally and 600 mm vertically.

The use of rectangular wall ties to tie walls made with any type of masonry units is permitted. The use of Z wall ties to tie walls made with other than hollow masonry units is permitted. Cross wires of joint reinforcement are permitted to be used in lieu of wall ties.

7.1.5.3 **Noncomposite action**. Masonry designed for noncomposite action shall comply to the following provisions:

7.1.5.3.1 Each wythe shall be designed to resist individually the effects of loads imposed on it.

Unless a more detailed analysis is performed, the following requirements shall be satisfied:

(a) Collar joints shall not contain headers, grout, or mortar.

(b) Gravity loads from supported horizontal members shall be resisted by the wythe nearest to the center of span of the supported member. Any resulting bending moment about the weak axis of the wall shall be distributed to each wythe in proportion to its relative stiffness.

(c) Loads acting parallel to the plane of a wall shall be carried only by the wythe on which they are applied. Transfer of stresses from such loads between wythes shall be neglected.

(d) Loads acting transverse to the plane of a wall shall be resisted by all wythes in proportion to their relative flexural stiffnesses.

(e) Specified distances between wythes shall not exceed a width of 100 mm unless a detailed wall tie analysis is performed.

7.1.5.3.2 Wythes of walls designed for noncomposite action shall be connected by wall ties meeting the requirements of Section 7.1.5.2.4 or by adjustable ties. Where the cross wires of joint reinforcement are used as ties, the joint reinforcement shall be ladder-type. Wall ties shall be without cavity drips.

Adjustable ties shall meet the following requirements:

(a) One tie shall be provided for each 0.16 m^2 of wall area.

(b) Horizontal and vertical spacing shall not exceed 400 mm.

(c) Adjustable ties shall not be used when the misalignment of bed joints from one wythe to the other exceeds 32 mm.

(d) Maximum clearance between connecting parts for the tie shall be 1.5 mm.

(e) Pintle ties shall have at least two pintle legs of wire size (WD 5).

7.1.6 **Columns.** Design of columns shall meet the general requirements of this section.

7.1.6.1 Minimum side dimension shall be 200 mm nominal.

7.1.6.2 The ratio between the effective height and least nominal dimension shall not exceed 25.

7.1.6.3 Columns shall be designed to resist applied loads. As a minimum, columns shall be designed to resist loads with an eccentricity equal to 0.1 times each side dimension. Consider each axis independently.

7.1.6.4 Vertical column reinforcement shall not be less than 0.0025 A_n nor exceed 0.04 A_n. The minimum number of bars shall be four.

7.1.6.5 **Lateral ties.** Lateral ties shall conform to the following:

a) Longitudinal reinforcement shall be enclosed by lateral ties at least 10 mm in diameter.

b) Vertical spacing of lateral ties shall not exceed 16 longitudinal bar diameters, 48 lateral tie bar or wire diameters, or least cross-sectional dimension of the member.

c) Lateral ties shall be arranged such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a lateral tie with an included angle of not more than 135 degrees. No bar shall be farther than 150 mm clear on each side along the lateral tie from such a laterally supported bar. Lateral ties shall be placed in either a mortar joint or in grout. Where longitudinal bars are located around the perimeter of a circle, a complete circular lateral is permitted. Lap length for circular ties shall be 48 tie diameters.

d) Lateral ties shall be located vertically not more than one-half lateral tie spacing above the top of footing or slab in any story, and shall be spaced as provide herein to not more than one-half a lateral tie spacing below the lowest horizontal reinforcement in beam, girder, slab, or drop panel above.

e) Where beams or brackets frame into a column from four directions, lateral ties may be terminated not more than 76 mm below the lowest reinforcement in the shallowest of such beams or brackets.

7.1.6.6 Masonry columns used only to support light-frame roofs of car-ports, porches, sheds or similar structures with a maximum area of 42 m^2 assigned to Seismic Design Category A, B or C are permitted to be designed and constructed as follows:

1. Concrete masonry materials shall be in accordance with Section 3.1. Clay or shale masonry units shall be in accordance with Section 3.2.
2. The nominal cross-sectional dimension of columns shall not be less than 200 mm.
3. Columns shall be reinforced with not less than one Dia 12 mm bar centered in each cell of the column.
4. Columns shall be grouted solid.
5. Columns shall not exceed 3.65 m in height.
6. Roofs shall be anchored to the columns. Such anchorage shall be capable of resisting the design load specified in SBC 301.
7. Where such columns are required to resist uplift loads, the columns shall be anchored to their footings with two Dia 12 mm bars extending a minimum of 600 mm into the columns and bent horizontally a minimum of 400 mm in opposite directions into the footings. One of these bars is permitted to be the reinforcing bar specified in Item 3 above. The total weight of a column and its footing shall not be less than 1.5 times the design uplift load.

7.1.7 **Pilasters**

7.1.7.1 Walls interfacing with pilasters shall not be considered as flanges unless the provisions of Section 3.13.4.2 are met.

7.1.7.2 Where vertical reinforcement is provided to resist axial compressive stress, lateral ties shall meet all applicable requirements of Section 7.1.6.5.

7.1.8 **Load transfer at horizontal connections**

7.1.8.1 Walls, columns, and pilasters shall be designed to resist all loads, moments, and shears applied at intersections with horizontal members.

7.1.8.2 Effect of lateral deflection and translation of members providing lateral support shall be considered.

7.1.8.3 Devices used for transferring lateral support from members that intersect walls, columns, or pilasters shall be designed to resist the forces involved. For columns, a force of not less than 4500 N shall be used.

7.1.9 **Concentrated loads**

7.1.9.1 For computing compressive stress f_a for walls laid in running bond, concentrated loads shall not be distributed over the length of supporting wall in excess of the length of wall equal to the width of bearing areas plus four times the thickness of the supporting wall, but not to exceed the center-to-center distance between concentrated loads.

7.1.9.2 Bearing stresses shall be computed by distributing the bearing load over an area determined as follows:

(a) The direct bearing area A_1, or

(b) $A_1\sqrt{A_2 / A_1}$ but not more than $2A_1$, where A_2 is the supporting surface wider than A_1 on all sides, or A_2 is the area of the lower base of the largest frustum of a right pyramid or cone having A_1 as upper base sloping at 45 degrees from the horizontal and wholly contained within the support. For walls in other than running bond, area A_2, shall terminate at head joints.

7.1.9.3 Bearing stresses shall not exceed 0.25 f_m'.

7.1.10 **Development of reinforcement embedded in grout**

7.1.10.1 **General.** The calculated tension or compression in the reinforcement at each section shall be developed on each side of the section by embedment length, hook or mechanical device, or a combination thereof. Hooks shall not be used to develop bars in compression.

7.1.10.2 **Embedment of bars and wires in tension.** The embedment length of bars and wire shall be determined by Eq. (7-8), but shall not be less than 300 mm for bars and 150 mm for wire.

$$l_d = 0.22\, d_b\, F_s \qquad \textbf{Eq. (7-8)}$$

When epoxy-coated bars or wires are used, development length determined by Eq. (7-8) shall be increased by 50 percent.

7.1.10.3 **Embedment of flexural reinforcement**

7.1.10.3.1 **General**

7.1.10.3.1.1 Tension reinforcement is permitted to be developed by bending across the neutral axis of the member to be anchored or made continuous with reinforcement on the opposite face of the member.

7.1.10.3.1.2 Critical sections for development of reinforcement in flexural members are at points of maximum steel stress and at points within the span where adjacent reinforcement terminates or is bent.

7.1.10.3.1.3 Reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the effective depth of the member or $12d_b$, whichever is greater, except at supports of simple spans and at the free end of cantilevers.

7.1.10.3.1.4 Continuing reinforcement shall extend a distance l_d beyond the point where bent or terminated tension reinforcement is no longer required to resist flexure as required by Section 7.1.10.2.

7.1.10.3.1.5 Flexural reinforcement shall not be terminated in a tension zone unless one of the following conditions is satisfied:

(a) Shear at the cutoff point does not exceed two-thirds of the allowable shear at the section considered.

(b) Stirrup area in excess of that required for shear is provided along each terminated bar or wire over a distance from the termination point equal to three-fourths the effective depth of the member. Excess stirrup area, Av, shall not be less than 60 $b_w s/f_y$. Spacing s shall not exceed d/(8 β b).

(c) Continuous reinforcement provides double the area required for flexure at the cut-off point and shear does not exceed three-fourths the allowable shear at the section considered.

7.1.10.3.1.6 Anchorage complying with Section 7.1.10.2 shall be provided for tension reinforcement in corbels, deep flexural members, variable-depth arches, members where flexural reinforcement is not parallel with the compression face, and in other cases where the stress in flexural reinforcement does not vary linearly in proportion to the moment.

7.1.10.3.2 **Development of positive moment reinforcement** When a wall or other flexural member is part of a primary lateral resisting system, at least 25 percent of the positive moment reinforcement shall extend into the support and be anchored to develop a stress equal to the F_s in tension.

7.1.10.3.3 **Development of negative moment reinforcement**

7.1.10.3.3.1 Negative moment reinforcement in a continuous, restrained, or cantilever member shall be anchored in or through the supporting member in accordance with the provisions of Section 7.1.10.1.

7.1.10.3.3.2 At least one-third of the total reinforcement provided for moment at a support shall extend beyond the point of inflection the greater distance of the effective depth of the member or one-sixteenth of the span.

7.1.10.4 **Hooks**

7.1.10.4.1 Standard hooks in tension shall be considered to develop an equivalent embedment length, l_e, equal to 11.25 d_b.

7.1.10.4.2 The effect of hooks for bars in compression shall be neglected in design computations.

7.1.10.5 **Development of Shear reinforcement**

7.1.10.5.1 Bar and wire reinforcement

7.1.10.5.1.1 Shear reinforcement shall extend to a distance d from the extreme compression face and shall be carried as close to the compression and tension surfaces of the member as cover requirements and the proximity of other reinforcement permit. Shear reinforcement shall be anchored at both ends for its calculated stress.

7.1.10.5.1.2 The ends of single leg or U-stirrups shall be anchored by one of the following means:

(a) A standard hook plus an effective embedment of 0.5 l_d. The effective embedment of a stirrup leg shall be taken as the distance between mid depth of the member $d/2$ and the start of the hook (point of tangency).

(b) For bar (Dia 16) and (WD 16.0) wire and smaller, bending around longitudinal reinforcement through at least 135 degrees plus an embedment of 0.33 l_d. The 0.33 l_d embedment of a stirrup leg shall be taken as the distance between mid depth of member $d/2$ and start of hook (point of tangency).

7.1.10.5.1.3 Between the anchored ends, each bend in the continuous portion of a transverse U-stirrup shall enclose a longitudinal bar.

7.1.10.5.1.4 Longitudinal bars bent to act as shear reinforcement, where extended into a region of tension, shall be continuous with longitudinal reinforcement and, where extended into a region of compression, shall be developed beyond mid depth of the member $d/2$.

7.1.10.5.1.5 Pairs of U-stirrups or ties placed to form a closed unit shall be considered properly spliced when length of laps are 1.7 l_d. In grout at least 450 mm deep, such splices with $A_v\, f_y$ not more than 40000 N per leg may be considered adequate if legs extend the full available depth of grout.

7.1.10.5.2 **Welded wire fabric**

7.1.10.5.2.1 For each leg of welded wire fabric forming simple U-stirrups, there shall be either:

(a) Two longitudinal wires at a 50 mm spacing along the member at the top of the U, or

(b) One longitudinal wire located not more than $d/4$ from the compression face and a second wire closer to the compression face and spaced not less than 50 mm from the first wire. The second wire shall be located on the stirrup leg beyond a bend, or on a bend with an inside diameter of bend not less than 8 d_b.

7.1.10.5.2.2 For each end of a single leg stirrup of welded smooth or deformed wire fabric, there shall be two longitudinal wires spaced minimum of 50 mm with the inner wire placed at a distance at least $d/4$ or 50 mm from middepth of member $d/2$. Outer longitudinal wire at tension face shall not be farther from the face than the portion of primary flexural reinforcement closest to the face.

7.1.10.6 **Splices of reinforcement –** Lap splices, welded splices, or mechanical connections are permitted in accordance with the provisions of this section. All welding shall conform to AWS D 1.4.

7.1.10.6.1 **Lap Splices**

7.1.10.6.1.1 The minimum length of lap splices for reinforcing bars in tension or compression $l_{ld,}$ shall be calculated by Eq (7-10), but shall not be less than 400 mm.

$$l_{ld} = \frac{1.95 d_b^2 f_y \gamma}{K\sqrt{f'_m}} \qquad \textbf{Eq. (7-10)}$$

Where:

d_b = Diameter of reinforcement, mm.

f_y = Specified yield stress of the reinforcement or the anchor bolt. MPa.

f'_m = Specified compressive strength of masonry at age of 28 days. MPa.

l_{ld} = Minimum lap splice length, mm.

K = The lesser of the masonry cover, clear spacing between adjacent reinforcement or five times d_b, mm.

γ = 1.0 for Dia 10 through Dia 16 mm reinforcing bars. 1.4 for Dia 20 and Dia 22 mm reinforcing bars. 1.5 for Dia 25 and Dia 28 mm reinforcing bars.

7.1.10.6.1.2 Bars spliced by noncontact lap splices shall not be spaced transversely farther apart than one-fifth the required length of lap nor more than 200 mm.

7.1.10.6.1.3 Splices for large bars. Reinforcing bars larger than Dia 28 mm in size shall be spliced using mechanical connectors in accordance with Section 7.1.10.6.3.

7.1.10.6.2 **Welded splices** - Welded splices shall have the bars butted and welded to develop in tension at least 125% of the specified yield strength of the bar.

7.1.10.6.3 **Mechanical connections** - Mechanical connections shall have the bars connected to develop in tension or compression, as required, at least 125% of the specified yield strength of the bar.

7.1.10.6.4 **End-bearing splices**

7.1.10.6.4.1 In bars required for compression only, the transmission of compressive stress by bearing of square cut ends held in concentric contact by a suitable device is permitted.

7.1.10.6.4.2 Bar ends shall terminate in flat surfaces within 1½ degree of a right angle to the axis of the bars and shall be fitted within 3 degrees of full bearing after assembly.

7.1.10.6.4.3 End-bearing splices shall be used only in members containing closed ties, closed stirrups, or spirals.

7.1.11 **Maximum bar size** The bar diameter shall not exceed one-eighth of the nominal wall thickness and shall not exceed one-quarter of the least dimension of the cell, course or collar joint in which it is placed

7.1.12 **Maximum reinforcement percentage** Special reinforced masonry shear walls having a shear span ratio M/Vd. Equal to or greater than 1.0 and having an axial load, P greater than 0.05 $f'_m A_n$ which are subjected to in-plane forces, shall have a maximum reinforcement ratio, ρ_{max}, not greater than that computed as follows:

$$\rho_{max} = \frac{nf'_m}{2f_y\left(n + \frac{f_y}{f'_m}\right)} \quad \textbf{Eq. (7-9)}$$

The maximum reinforcement ratio does not apply in the out-of-plane direction.

7.1.13 Special inspection during construction shall be provided as set forth in SBC 302.

SECTION 7.2
UNREINFORCED MASONRY

7.2.1 **Scope.** This section provides requirements for unreinforced masonry as defined in Chapter 2, except as otherwise indicated in Section 7.2.4.

7.2.2 **Stress in reinforcement.** The effect of stresses in reinforcement shall be neglected.

7.2.3 **Axial compression and flexure**

7.2.3.1 Members subjected to axial compression, flexure, or to combined axial compression and flexure shall be designed to satisfy Eq. (7-11) and Eq. (7-12).

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1 \quad \textbf{Eq. (7-11)}$$

$$P \leq (^1/_4)\, P_e \quad \textbf{Eq. (7-12)}$$

Where:

a) For members having an h/r ratio not greater than 99:

$$F_a = (^1/_4)\ f'_m \left[1 - \left(\frac{h}{140r}\right)^2\right] \quad \textbf{Eq. (7-13)}$$

b) For members having an h/r ratio greater than 99:

$$F_a = (^1/_4)\ f'_m \left(\frac{70r}{h}\right)^2 \quad \textbf{Eq. (7-14)}$$

c) $$F_b = (^1/_3)\ f'_m \quad \textbf{Eq. (7-15)}$$

d) $$P_e = \frac{\pi^2 E_m l_n}{h^2}\left(1 - 0.577\frac{e}{r}\right)^3 \quad \textbf{Eq. (7-16)}$$

7.2.3.2 Allowable tensile stresses due to flexure transverse to the plane of masonry member shall be in accordance with the values in Table 7.1.1.

7.2.4 **Axial tension.** The tensile strength of masonry shall be neglected in design when the masonry is subjected to axial tension forces.

7.2.5 **Shear**

7.2.5.1 Shear stresses due to forces acting in the direction considered shall be computed in accordance with Section 3.13.1 and determined by Eq. (7-17).

$$f_v = VQ/I_n b \quad \textbf{Eq.(7-17)}$$

7.2.5.2 In-plane shear stresses shall not exceed any of:

(a) $0.125\sqrt{f'_m}$

(b) 827 kPa

(c) $v + 0.45\, N_v / A_n$

where v :

= 255 kPa for masonry in running bond that is not grouted solid, or

= 255 kPa for masonry in other than running bond with open end units that are grouted solid, or

= 414 kPa for masonry in running bond that is grouted solid.

(d) 100 kPa for masonry in other than running bond with other than open end units that are grouted solid.

Table 7.1.1 Allowable flexural tension for clay and concrete masonry, kPa

Direction of flexural tensile Stress and masonry type	Mortar types			
	Portland cement/lime or mortar cement		Masonry cement or air entrained Portland cement/lime	
	M or S	N	M or S	N
Normal to bed joints Solid units	270	200	160	100
Hollow units,# Ungrouted	170	130	100	60
Fully grouted	445	430	420	400
Parallel to bed joints in running bond Solid units	550	400	330	200
Hollow Units – Ungrouted and partially grouted	345	260	200	130
Fully grouted	550	410	330	200

\# For partially grouted masonry, allowable stresses shall be determined on the basis of linear interpolation between hollow units that are fully grouted and ungrouted hollow units based on amount of grouting.

SECTION 7.3
REINFORCED MASONRY

7.3.1 **Scope.** This section provides requirements for the design of structures neglecting the contribution of tensile strength of masonry, except as provided in Section 7.3.5.

7.3.2 **Steel reinforcement.** Allowable stresses

7.3.2.1 **Tension.** Tensile stress in reinforcement shall not exceed the following:

(a) Grade 40 or Grade 50 reinforcement…… 138 MPa

(b) Grade 60 reinforcement ………..……….. 165 MPa

(c) Wire joint reinforcement……………….... 200 MPa

7.3.2.2 **Compression**

7.3.2.2.1 The compressive resistance of steel reinforcement shall be neglected unless lateral reinforcement is provided in compliance with the requirement of Section 7.1.6.5.

7.3.2.2.2 Compressive stress in reinforcement shall not exceed the lesser of $0.4f_y$ or 165 MPa.

7.3.3 **Axial compression and flexure**

7.3.3.1 Members subjected to axial compression, flexure, or combined axial compression and flexure shall be designed in compliance with Section 7.3.3.2 through Section 7.3.3.4.

7.3.3.2 **Allowable forces and stresses**

7.3.3.2.1 The compressive force in reinforced masonry due to axial load only shall not exceed that given by Eq. (7-18) or Eq. (7-19):

(a) For members having an h/r ratio not greater than 99:

$$P_a = (0.25\ f'_m\ A_n + 0.65\ A_{st}\ F_s)\left[1-\left(\frac{h}{140r}\right)^2\right] \qquad \textbf{Eq. (7-18)}$$

(b) For members having an h/r ratio greater than 99:

$$P_a = (0.25\ f'_m A_n + 0.65\ A_{st}\ F_s)\left(\frac{70r}{h}\right)^2 \qquad \textbf{Eq. (7-19)}$$

7.3.3.2.2 The compressive stress in masonry due to flexure or due to flexure in combination with axial load shall not exceed (1/3) f'_m provided the calculated compressive stress due to the axial load component, f_a, does not exceed the allowable stress, F_a, in Section 7.2.3.1.

7.3.3.3 **Effective compressive width per bar**

7.3.3.3.1 In running bond masonry and masonry in other than running bond with bond beams spaced not more than 1200 mm center-to-center, the width of the compression area used in stress calculations shall not exceed the least of:

(a) Center-to-center bar spacing.

(b) Six times the wall thickness.

(c) 1800 mm.

7.3.3.3.2 In masonry in other than running bond, with bond beams spaced more than. 1200 mm center-to-center, the width of the compression area used in stress calculations shall not exceed the length of the masonry unit.

7.3.3.4 **Beams**

7.3.3.4.1 Span length of members not built integrally with supports shall be taken as the clear span plus depth of member, but need to exceed the distance between centers of supports.

7.3.3.4.2 In analysis of members that are continuous over supports for determination of moments, span length shall be taken as the distance between centers of supports.

7.3.3.4.3 Length of bearing of beams on their supports shall be a minimum of 100 mm in the direction of span.

7.3.3.4.4 The compression face of beams shall be laterally supported at a maximum spacing of 32 times the beam thickness.

7.3.3.4.5 Beams shall be designed to meet the deflection requirements of Section 4.1.5.1.

7.3.4 **Axial tension and flexural tension.** Axial tension and flexural tension shall be resisted entirely by steel reinforcement.

7.3.5 **Shear**

7.3.5.1 Members that are not subjected to flexural tension shall be designed in accordance with the requirements of Section 7.2.5 or shall be designed in accordance with the following:

7.3.5.1.1 Reinforcement shall be provided in accordance with the requirements of Section 7.3.5.3.

7.3.5.1.2 The calculated shear stress, f_v, shall not exceed F_v, where F_v is determined in accordance with Section 7.3.5.2.3.

7.3.5.2 Members subjected to flexural tension shall be reinforced to resist the tension and shall be designed in accordance with the following:

7.3.5.2.1 Calculated shear stress in the masonry shall be determined by the relationship:

$$f_v = V/bd \qquad \textbf{Eq. (7-20)}$$

7.3.5.2.2 Where reinforcement is not provided to resist all of the calculated shear, f_v shall not exceed F_v, where:

(a) For flexural members:

$$F_v = 0.083\sqrt{f'_m} \qquad \textbf{Eq. (7-21)}$$

but shall not exceed 345 kPa.

(b) For shear walls,
where $M/V\text{d} < 1$

$$F_v = 0.028\,[4 - (M/V\text{d})]\sqrt{f'_m} \qquad \textbf{Eq. (7-22)}$$

but shall not exceed (0.55-0.31 (M/Vd))

where $M/V\text{d} \geq 1$,

$$F_v = 0.083\sqrt{f'_m} \qquad \textbf{Eq. (7-23)}$$

but shall not exceed 240kPa

7.3.5.2.3 Where shear reinforcement is provided in accordance with Section 7.3.5.3 to resist all of the calculated shear, f_v shall not exceed F_v, where:

(a) For flexural members:

$$F_v = 0.25\sqrt{f'_m} \qquad \textbf{Eq. (7-24)}$$

but shall not exceed 1000 kPa

(b) For shear walls,

where $M/V\mathrm{d} < 1$

$$F_v = 0.042\,[4 - (M/V\mathrm{d})]\,\sqrt{f'_m} \qquad \textbf{Eq. (7-25)}$$

but shall not exceed (0.82-0.31 (M/Vd))

where $M/V\mathrm{d} \geq 1$

$$F_v = 0.125\,\sqrt{f'_m} \qquad \textbf{Eq. (7-26)}$$

but shall not exceed 500 kPa

7.3.5.2.4 The ratio M/Vd shall always be taken as a positive number.

7.3.5.3 Minimum area of shear reinforcement required by Section 7.3.5.1 or 7.3.5.2.3 shall be determined by the following:

$$A_v = \frac{V\ s}{F_s\ d} \qquad \textbf{Eq. (7-27)}$$

7.3.5.3.1 Shear reinforcement shall be provided parallel to the direction of applied shear force. Spacing of shear reinforcement shall not exceed the lesser of $d/2$ or 1200 mm.

7.3.5.3.2 Reinforcement shall be provided perpendicular to the shear reinforcement and shall be at least equal to one-third A_v. The reinforcement shall be uniformly distributed and shall not exceed a spacing of 2.50 m.

7.3.5.4 In composite masonry walls, shear stresses developed in the planes of interfaces between wythes and filled collar joints or between wythes and headers shall meet the requirements of Section 7.1.5.2.2.

7.3.5.5 In cantilever beams, the maximum shear shall be used. In noncantilever beams, the maximum shear shall be used except that sections located within a distance $d/2$ from the face of support shall be designed for the same shear as that computed at a distance $d/2$ from the face of support when the following conditions are met:

(a) Support reaction, in direction of applied shear force, introduces compression into the end regions of member, and

(b) No concentrated load occurs between face of support and a distance $d/2$ from face.

CHAPTER 8
STRENGTH DESIGN OF MASONRY

SECTION 8.1
GENERAL

8.1.1 **Scope.** This Chapter provides minimum requirements for strength design of masonry. Masonry design by the strength design method shall comply with the requirements of Section 8.1 and either Section 8.2 or Section 8.3.

The minimum nominal thickness for hollow clay masonry in accordance with Section 8.2.2 shall be 100 mm.

8.1.2 **Required strength.** Required strength shall be determined in accordance with the strength design load combinations of SBC 301. Members subject to compressive axial load shall be designed for the maximum design moment accompanying the axial load. The factored moment, M_u, shall include the moment induced by relative lateral displacement.

8.1.3 **Design strength.** Masonry members shall be proportioned such that the design strength equals or exceeds the required strength. Design strength is the nominal strength multiplied by the strength reduction factor, ϕ, as specified in Section 8.1.4.

The design shear strength, ϕV_n, shall exceed the shear corresponding to the development of 1.25 times the nominal flexural strength, M_n, of the member, except that the nominal shear strength, V_n, need not exceed 2.5 times required shear strength, V_u.

8.1.3.1 **Seismic design provisions.** At each story level, at least 80 percent of the lateral stiffness shall be provided by lateral-force-resisting walls. Along each column line at a particular story level, at least 80% of the lateral stiffness shall be provided by lateral-force-resisting walls.

Exception: Where seismic loads are determined based on a seismic response modification factor, *R,* not greater than 1.5, piers and columns are permitted to be used to provide seismic load resistance.

8.1.4 **Strength reduction factors**

8.1.4.1 **Combinations of flexure and axial load in reinforced masonry.** The value of ϕ shall be taken as 0.90 for reinforced masonry subjected to flexure, axial load, or combinations thereof.

8.1.4.2 **Combinations of flexure and axial load in unreinforced masonry.** The value of ϕ shall be taken as 0.60 for unreinforced masonry subjected to flexure, axial load, or combinations thereof.

8.1.4.3 **Shear.** The value of ϕ shall be taken as 0.80 for masonry subjected to shear.

8.1.4.4 **Anchor bolts.** For cases where the nominal strength of an anchor bolt is controlled by masonry breakout, ϕ shall be taken as 0.50. For cases where the nominal strength of an anchor bolt is controlled by anchor bolt steel, ϕ shall be taken as 0.90. For cases where the nominal strength of an anchor bolt is controlled by

anchor pullout, ϕ shall be taken as 0.65.

8.1.4.5 **Development and splices of reinforcement.** For development and splicing of reinforcement, ϕ shall be taken as 0.80.

8.1.4.6 **Bearing.** For cases where bearing on masonry, ϕ shall be taken as 0.60.

8.1.5 Deformation requirements

8.1.5.1 **Drift limits.** Under loading combinations that include earthquake, masonry structures shall be designed so the calculated story drift, Δ, does not exceed the allowable story drift, Δ_a, obtained from SBC 301.

For determining drift, the calculated deflection shall be multiplied by C_d as indicated in SBC 301.

8.1.5.2 **Deflection of unreinforced (plain) masonry.** Deflection calculations for unreinforced (plain) masonry members shall be based on uncracked section properties.

8.1.5.3 **Deflection of reinforced masonry.** Deflection calculations for reinforced masonry members shall be based on cracked section properties. The flexural and shear stiffness properties assumed for deflection calculations shall not exceed one half of the gross section properties unless a cracked-section analysis is performed.

8.1.6 **Headed and bent-bar anchor bolts.** All embedded bolts shall be grouted in place with at least 13 mm of grout between the bolt and the masonry, except that 6.5 mm diameter bolts are permitted to be placed in bed joints that are at least 13 mm in thickness.

8.1.6.1 **Nominal axial tensile strength of headed anchor bolts.** The nominal axial tensile strength, B_{an}, of headed anchor bolts embedded in masonry shall be computed by Eq. (8-1) (strength governed by masonry breakout) and Eq. (8-2) (strength governed by steel). In computing the capacity, the smaller of the design strengths shall be used.

$$B_{an} = 0.332\, A_{\mathrm{pt}} \sqrt{f'_m} \qquad \textbf{Eq. (8-1)}$$

$$B_{an} = A_b f_y \qquad \textbf{Eq. (8-2)}$$

8.1.6.1.1 **Projected area of masonry for headed anchor bolts.** The projected area, A_{pt}, in Eq. (8-1) shall be determined by Eq. (8-3).

$$A_{pt} = \pi\, l_b^2 \qquad \textbf{Eq. (8-3)}$$

Where the projected areas, A_{pt}, of adjacent headed anchor bolts overlap, the projected area, A_{pt}, of each bolt shall be reduced by one-half of the overlapping area. The portion of the projected area overlapping an open cell, open head joint, or that is outside the wall shall be deducted from the value of A_{pt} calculated using Eq. (8-3).

8.1.6.1.2 **Effective embedment length for headed anchor bolts.** The effective embedment length for a headed anchor bolt, l_b, shall be the length of the embedment measured perpendicular from the masonry surface to the bearing surface of the anchor head. The minimum effective embedment length for headed anchor bolts resisting axial forces shall be 4 bolt diameters or 50 mm, whichever is greater.

8.1.6.2 **Nominal axial tensile strength of bent-bar anchor bolts.** The nominal axial tensile strength, B_{an}, for bent-bar anchor bolts (J- or L-bolts) embedded in masonry shall be computed by Eq. (8-4) (strength governed by masonry breakout), Eq. (8-5) (strength governed by steel), and Eq. (8-6) (strength governed by anchor pullout). In computing the capacity, the smaller of the design strengths shall be used.

$$B_{an} = 0.332 A_{pt} \sqrt{f_m'} \qquad \textbf{Eq. (8-4)}$$

$$B_{an} = A_b f_y \qquad \textbf{Eq. (8-5)}$$

$$B_{an} = 1.5\ f_m' e_b d_b + [3.07\pi\ (l_b + e_b + d_b) d_b] \qquad \textbf{Eq. (8-6)}$$

The second term in Eq. (8-6) shall be included only if the specified quality assurance program includes verification that shanks of J- and L-bolts are free of debris, oil, and grease when installed.

8.1.6.2.1 **Projected area of masonry for bent-bar anchor bolts.** The projected area, A_{pt} in Eq. (8-4) shall be determined by Eq. (8-7).

That portion of the projected area overlapping an open cell, open head joint, or that is outside the wall shall be deducted from the value of A_{pt} calculated using Eq. (8-7).

$$A_{pt} = \pi\ l_b^2 \qquad \textbf{Eq. (8-7)}$$

Where the projected areas, A_{pt}, of adjacent bent – bar anchor bolts overlap, the projected area, A_{pt}, of each bolt shall be one-half the overlapping area.

That portion of the projected area overlapping an open cell, open head joint, or that is outside the wall shall be deducted from value of A_{pt} calculated using Eq. (8-7).

8.1.6.2.2 **Effective embedment length of bent-bar anchor bolts.** The effective embedment for a bent-bar anchor bolt, l_b, shall be the length of embedment measured perpendicular from the masonry surface to the bearing surface of the bent end, minus one anchor bolt diameter. The minimum effective embedment length for bent-bar anchor bolts resisting axial forces shall be 4 bolt diameters or 50 mm, whichever is greater.

8.1.6.3 **Nominal shear strength of headed and bent-bar anchor bolts.** The nominal shear strength, B_{vn}, shall be computed by Eq. (8-8) (strength governed by masonry breakout) and Eq. (8-9) (strength governed by steel). In computing the capacity, the smaller of the design strengths shall be used.

$$B_{vn} = 0.332\ A_{pv} \sqrt{f_m'} \qquad \textbf{Eq. (8-8)}$$

$$B_{vn} = 0.6\ A_b f_y \qquad \textbf{Eq. (8-9)}$$

8.1.6.3.1 **Projected area of masonry.** The area A_{pv}, in Eq. (8-8) shall be determined from Eq. (8-10).

$$A_{pv} = \frac{\pi\ l_{be}^{\ 2}}{2} \qquad \textbf{Eq. (8-10)}$$

8.1.6.3.2 **Minimum effective embedment length.** The minimum effective embedment length for headed or bent-bar anchor bolts resisting shear forces shall be 4 bolt diameters, or 50 mm, whichever is greater.

8.1.6.4 **Combined axial and shear strength of anchor bolts.** Anchor bolts subjected to combined shear and tension shall be designed to satisfy Eq. (8-11).

$$\frac{b_{af}}{\phi\ B_{an}} + \frac{b_{vf}}{\phi\ B_{vn}} \leq 1 \qquad \textbf{Eq. (8-11)}$$

ϕB_{an} and ϕB_{vn}, used in Eq. (8-11) shall be the governing design tensile and shear strengths, respectively.

8.1.7 Material properties

8.1.7.1 Compressive strength

8.1.7.1.1 **Masonry compressive strength.** The specified compressive strength of masonry, $f_m^{'}$ shall equal or exceed 10.5 MPa. The value of $f_m^{'}$ used to determine nominal strength values in this chapter shall not exceed 28 MPa for concrete masonry and shall not exceed 42 MPa for clay masonry.

8.1.7.1.2 **Grout compressive strength.** For concrete masonry, the specified compressive strength of grout, $f_g^{'}$, shall equal or exceed the specified compressive strength of masonry, $f_m^{'}$, but shall not exceed 35 MPa. For clay masonry, the specified compressive strength of grout, $f_g^{'}$, shall not exceed 42 MPa.

8.1.7.2 Masonry modulus of rupture

8.1.7.2.1 **Out-of-plane bending.** The modulus of rupture, f_r, for masonry elements subjected to out-of-plane bending shall be taken from Table 8.1.1.

8.1.7.2.2 **In-plane bending.** For masonry subjected to in-plane loads, the modulus of rupture, f_r, normal to the bed joints shall be taken as 1.75 MPa. The modulus of rupture used for masonry parallel to the bed joints shall be taken as 1.75 MPa. For grouted stack bond masonry, tension parallel to the bed joints shall be assumed to be resisted only by the continuous horizontal grout section.

8.1.7.3 **Reinforcement strength.** Masonry design shall be based on a reinforcement strength equal to the specified yield strength of reinforcement, f_y, which shall not exceed 420 MPa. The actual yield strength shall not exceed 1.3 times the specified yield strength. The compressive resistance of steel reinforcement shall be neglected unless lateral reinforcement is provided in compliance with the requirements of lateral ties.

Table 8.1.1 — Modulus of rupture *(f_r), kPa*

Direction of flexural tensile stress and masonry type	Mortar types			
	Portland cement/lime or mortar cement		Masonry cement or air entrained Portland cement/lime	
	M or S	N	M or S	N
Normal to bed joints in running or stack bond				
Solid units	700	525	420	266
Hollow units[1]				
Ungrouted	441	336	266	158
Fully grouted	1190	1015	721	511
Parallel to bed joints in running or stack bond	1400	1050	840	525
Solid units				
Hollow units				
Ungrouted and partially grouted	875	665	525	336
Fully grouted	1400	1050	840	525
Parallel to bed joints in stack bond	0	0	0	0

[1] For partially grouted masonry, modulus of rupture values shall be determined on the basis of linear interpolation between hollow units that are fully grouted and ungrouted based on amount (percentage) of grouting.

SECTION 8.2
REINFORCED MASONRY

8.2.1 **Scope.** The requirements of this section are in addition to the requirements of Section 8.1 and govern masonry design in which reinforcement is used to resist tensile forces.

8.2.2 **Design assumptions.** The following assumptions apply to the design of reinforced masonry:

(a) There is strain continuity between the reinforcement, grout, and masonry such that all applicable loads are resisted in a composite manner.

(b) The nominal strength of reinforced masonry cross-sections for combined flexure and axial load shall be based on applicable conditions of equilibrium.

(c) The maximum usable strain, ε_{mu} at the extreme masonry compression fiber shall be assumed to be 0.0035 for clay masonry and 0.0025 for concrete masonry.

(d) Strain in reinforcement and masonry shall be assumed to be directly proportional to the distance from the neutral axis.

(e) Reinforcement stress below specified yield strength, f_y, shall be taken as E_s times steel strain. For strains greater than that corresponding to f_y, stress in reinforcement shall be taken equal to f_y.

(f) The tensile strength of masonry shall be neglected in calculating flexural strength but shall be considered in calculating deflection.

(g) The relationship between masonry compressive stress and masonry strain shall be assumed to be defined by the following:

Masonry stress of $0.80 f_m^{'}$ shall be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance a = 0.80 c, from the fiber of maximum compressive strain. The distance, c, from the fiber of maximum strain to the neutral axis shall be measured perpendicular to that axis. For out-of-plane bending, the width of the equivalent stress block shall not be taken greater than six times the nominal thickness of the masonry wall or the spacing between reinforcement, whichever is less. For in-plane bending of flanged walls, the effective flange width shall not exceed six times the thickness of the flange.

8.2.3 Reinforcement requirements and details

8.2.3.1 Reinforcing bar size limitations. Reinforcing bars used in masonry shall not be larger than (Dia 28). The nominal bar diameter shall not exceed one-eighth of the nominal member thickness and shall not exceed one-quarter of the least clear dimension of the cell, course, or collar joint in which it is placed. The area of reinforcing bars placed in a cell or in a course of hollow unit construction shall not exceed 4 percent of the cell area.

8.2.3.2 Standard hooks. The equivalent embedment length to develop standard hooks in tension, l_e, shall be determined by Eq. (8-12):

$$l_e = 13 d_b \qquad \textbf{Eq. (8-12)}$$

8.2.3.3 Development. The required tension or compression reinforcement shall be developed in accordance with the following provisions:

The required development length of reinforcement shall be determined by Eq. (8-13), but shall not be less than 300 mm.

$$l_d = \frac{l_{de}}{\phi} \qquad \textbf{Eq. (8-13)}$$

where:

$$l_d = \frac{1.5 d_b^2 f_y \gamma}{K \sqrt{f_m^{'}}} \qquad \textbf{Eq. (8-14)}$$

K = shall not exceed the lesser of the masonry cover, clear spacing between adjacent reinforcement, nor 5 times d_b.

γ = 1.0 for (Dia 10) through (Dia 16) bars;

γ = 1.4 for (Dia 20) and (Dia 22) bars; and

γ = 1.5 for (Dia 25) and (Dia 28) bars.

8.2.3.3.1 Development of shear reinforcement. Shear reinforcement shall extend the depth of the member less cover distances.

8.2.3.3.1.1 Except at wall intersections, the end of a horizontal reinforcing bar needed to satisfy shear strength requirements of Section 8.2.4.1.2 shall be bent around the edge vertical reinforcing bar with a 180-degree hook. The ends of single leg or U-stirrups shall be anchored by one of the following means:

(a) A standard hook plus an effective embedment of l_d/2. The effective embedment of a stirrup leg shall be taken as the distance between the mid-depth of the member, *d/2*, and the start of the hook (point of

tangency).

(b) For (Dia 16) bars and smaller, bending around longitudinal reinforcement through at least 135 degrees plus an embedment of $l_d/3$. The $l_d/3$ embedment of a stirrup leg shall be taken as the distance between mid-depth of the member, *d/2*, and the start of the hook (point of tangency).

(c) Between the anchored ends, each bend in the continuous portion of a transverse U-stirrup shall enclose a longitudinal bar.

8.2.3.3.1.2 At wall intersections, horizontal reinforcing bars needed to satisfy shear strength requirements of Section 8.2.4.1.2 shall be bent around the edge vertical reinforcing bar with a 90-degree standard hook and shall extend horizontally into the intersecting wall a minimum distance at least equal to the development length.

8.2.3.4 **Splices.** Reinforcement splices shall comply with one of the following:

(a) The minimum length of lap for bars shall be 300 mm or the length determined by Eq. (8-15), whichever is greater.

$$l_d = \frac{l_{de}}{\phi} \qquad \textbf{Eq. (8-15)}$$

(b) A welded splice shall have the bars butted and welded to develop at least 125% of the yield strength, f_y, of the bar in tension or compression, as required. Welded splices shall be of ASTM A 706 steel reinforcement. Welded splices shall not be permitted in plastic hinge zones of intermediate or special reinforced walls or special moment frames of masonry.

(c) Mechanical splices shall be classified as Type 1 or 2 according to SBC 304. Type 1 mechanical splices shall not be used within a plastic hinge zone or within a beam-column joint of intermediate or special reinforced masonry shear walls or special moment frames. Type 2 mechanical splices are permitted in any location within a member.

8.2.3.5 **Maximum reinforcement percentages**

8.2.3.5.1 For structures designed using an *R* value greater than 1.5, the ratio of reinforcement, ρ, shall not exceed the lesser of the values required to satisfy the following two critical strain conditions:

(a) For walls subjected to in-plane forces, for columns, and for beam, a strain of 5 times yield in the extreme tension reinforcement and a maximum masonry strain defined by Section 8.2.2(c).

(b) For walls subjected to out-of-plane forces, a strain of 1.3 times yield in the extreme tension reinforcement and a maximum masonry strain defined by Section 8.2.2(c).

In calculating the maximum reinforcement ratio for each case, equilibrium shall include unfactored gravity axial loads. The stress in the tension reinforcement shall be assumed to be 1.25 f_y. Tension in the masonry shall be neglected. The strength of the compression zone shall be calculated as 80 percent of f_m' times 80 percent of the area of the compressive zone. Stress in reinforcement in the compression zone shall be based on a linear strain distribution.

8.2.3.5.2 For structures designed using an *R* value less than or equal to 1.5, the ratio of reinforcement, ρ, shall not exceed the ratio as calculated using the following

critical strain condition:

A strain of 2 times yield in the extreme tension reinforcement and a maximum masonry strain defined by Section 8.2.2(c). In calculating the maximum reinforcement ratio, equilibrium shall include unfactored gravity axial loads. The stress in the tension reinforcement shall be assumed to be 1.25 f_y. Tension in the masonry shall be neglected. The strength of the compression zone shall be calculated as 80% of f'_m times 80 percent of the area of the compressive zone. Stress in reinforcement in the compression zone shall be based on a linear strain distribution.

8.2.3.6 **Bundling of reinforcing bars.** Reinforcing bars shall not be bundled.

8.2.4 Design of beams, piers, and columns

Member design forces shall be based on an analysis that considers the relative stiffness of structural members. The calculation of lateral stiffness shall include the contribution of all beam, piers, and columns. The effects of cracking on member stiffness shall be considered.

8.2.4.1 Nominal strength

8.2.4.1.1 **Nominal axial and flexural strength**. The nominal axial strength, P_n, and the nominal flexural strength, M_n, of a cross section shall be determined in accordance with the design assumptions of Section 8.2.2 and the provisions of Section 8.2.4.1. Using the slenderness-dependent modification factors of Eq. (8-16) $(1-(h/140r)^2)$ and Eq. (8-17) $(70r/h)^2$, as appropriate, the nominal axial strength shall be modified for the effects of slenderness. The nominal flexural strength at any section along a member shall not be less than one fourth of the maximum nominal flexural strength at the critical section.

The nominal axial compressive strength shall not exceed Eq. (8-16) or Eq. (8-17), as appropriate.

(a) For members having an *h/r* ratio not greater than 99:

$$P_n = 0.80[0.80\ f'_m\ (A_n - A_s) + f_y\ A_s\ ] \left(1 - \left(\frac{h}{140r}\right)^2 \right) \qquad \textbf{Eq. (8-16)}$$

(b) For members having an *h/r* ratio greater than 99:

$$P_n = 0.80[0.80\ f'_m\ (A_n - A_s) + f_y\ A_s\ ] \left(\frac{70r}{h}\right)^2 \qquad \textbf{Eq. (8-17)}$$

8.2.4.1.2 **Nominal shear strength.** Nominal shear strength, V_n, shall be computed using Eq. (8-18) and either Eq. (8-19) or Eq. (8-20), as appropriate.

$$V_n = V_m + V_s \qquad \textbf{Eq. (8-18)}$$

where V_n shall not exceed the following:

(a) Where $M/Vd_v \leq 0.25$:

$$V_n \leq 6A_n \sqrt{f'_m} \qquad \textbf{Eq. (8-19)}$$

(b) Where $M/Vd_v \geq 1.00$

$$V_n \leq 4A_n \sqrt{f'_m} \qquad \textbf{Eq. (8-20)}$$

(c) The maximum value of V_n for M/Vd_v between 0.25 and 1.0 may be interpolated.

8.2.4.1.2.1 **Nominal masonry shear strength** — Shear strength provided by the masonry, V_m, shall be computed using Eq. (8-21):

$$V_m = 0.83\left[4.0 - 1.75\left(\frac{M}{Vd_v}\right)\right] A_n \sqrt{f'_m} + 0.25\,P \qquad \textbf{Eq. (8-21)}$$

M/Vd_v need not be taken greater than 1.0.

8.2.4.1.2.2 **Nominal shear strength provided by reinforcement** — Nominal shear strength provided by reinforcement, V_s, shall be computed as follows:

$$V_s = 0.5\left(\frac{A_v}{s}\right) f_y\, d_v \qquad \textbf{Eq. (8-22)}$$

8.2.4.2 **Beams**

8.2.4.2.1 Members designed primarily to resist flexure shall comply with the requirements of Section 8.2.4.2. The factored axial compressive force on a beam shall not exceed $0.05 A_n f'_m$.

8.2.4.2.2 **Longitudinal reinforcement**

8.2.4.2.2.1 The variation in longitudinal reinforcing bars in a beam shall not be greater than one bar size. Not more than two bar sizes shall be used in a beam.

8.2.4.2.2.2 The nominal flexural strength of a beam shall not be less than 1.3 times the nominal cracking moment strength of the beam, M_{cr}. The modulus of rupture, f_r, for this calculation shall be determined in accordance with Section 8.1.7.2.

8.2.4.2.3 **Transverse reinforcement.** Transverse reinforcement shall be provided where V_u exceeds ϕV_m. The factored shear, V_u, shall include the effects of lateral load. When transverse reinforcement is required, the following provisions shall apply:

(a) Transverse reinforcement shall be a single bar with a 180-degree hook at each end.

(b) Transverse reinforcement shall be hooked around the longitudinal reinforcement.

(c) The minimum area of transverse reinforcement shall be 0.0007 bd_v.

(d) The first transverse bar shall not be located more than one fourth of the beam depth, d_v, from the end of the beam.

(e) The maximum spacing shall not exceed one-half the depth of the beam nor 1200 mm.

8.2.4.2.4 **Construction.** Beams shall be grouted solid.

8.2.4.2.5 **Dimensional limits.** Dimensions shall be in accordance with the following:

(a) The clear distance between locations of lateral bracing of the compression side of the beam shall not exceed 32 times the least width of the compression area.

(b) The nominal depth of a beam shall not be less than 200 mm.

8.2.4.3 **Piers**

8.2.4.3.1 The factored axial compression force on the piers shall not exceed $0.3 A_n f'_m$.

8.2.4.3.2 Longitudinal reinforcement. A pier subjected to in-plane stress reversals shall be reinforced symmetrically about the neutral axis of the pier. The longitudinal reinforcement of all piers shall comply with the following:

(a) One bar shall be provided in the end cells.

(b) The minimum area of longitudinal reinforcement shall be 0.0007 bd.

(c) Longitudinal reinforcement shall be uniformly distributed throughout the depth of the element.

8.2.4.3.3 Dimensional limits. Dimensions shall be in accordance with the following:

(a) The nominal thickness of a pier shall not be less than 150 mm and shall not exceed 400 mm.

(b) The distance between lateral supports of a pier shall not exceed 25 times the nominal thickness of a pier except as provided for in Section 8.2.4.3.3(c).

(c) When the distance between lateral supports of a pier exceeds 25 times the nominal thickness of the pier, design shall be based on the provisions of Section 8.2.5.

(d) The nominal length of a pier shall not be less than three times its nominal thickness nor greater than six times its nominal thickness. The clear height of a pier shall not exceed five times its nominal length.

Exception: When the factored axial force at the location of maximum moment is less than 0.05 f'_m A_g, the length of a pier may be equal to the thickness of the pier.

8.2.4.4 Columns

8.2.4.4.1 Longitudinal reinforcement. Longitudinal reinforcement shall be a minimum of four bars, one in each corner of the column, and shall comply with the following:

(a) Maximum reinforcement area shall be determined in accordance with Section 8.2.3.5, but shall not exceed 0.04 A_n.

(b) Minimum reinforcement area shall be 0.0025 A_n.

(c) Longitudinal reinforcement shaI1 be uniformly distributed throughout the depth of the element.

8.2.4.4.2 Lateral ties. Lateral ties shall be provided in accordance with Section 7.1.6.5.

8.2.4.4.3 Construction. Columns shall be solid grouted.

8.2.4.4.4 Dimensional limits. Dimensions shall be in accordance with the following:

(a) The nominal width of a column shall not be less than 200 mm.

(b) The distance between lateral supports of a column shall not exceed 30 times its nominal width.

(c) The nominal depth of a column shall not be less than 200 mm and not greater than three times its nominal width.

8.2.5 Wall design for out-of-plane loads

8.2.5.1 General. The requirements of Section 8.2.5 are for the design of walls for out-of-plane loads.

8.2.5.2 Maximum reinforcement. The maximum reinforcement ratio shall be determined by Section 8.2.3.5.

8.2.5.3 **Moment and deflection calculations.** All moment and deflection calculations in Section 8.2.5.4 are based on simple support conditions top and bottom. For other support and fixity conditions, moments and deflections shall be calculated using established principles of mechanics.

8.2.5.4 **Walls with factored axial stress of 0.05 f'_m or less.** The procedures set forth in this section shall be used when the factored axial load stress at the location of maximum moment satisfies the requirement computed by Eq. (8-23).

$$\left(\frac{P_u}{A_g}\right) \leq 0.05\, f'_m \qquad \textbf{Eq. (8-23)}$$

Factored moment and axial force shall be determined at the midheight of the wall and shall be used for design. The factored moment, M_u, at the midheight of the wall shall be computed using Eq. (8-24).

$$M_u = \frac{w_u h^2}{8} + P_{uf}\frac{e_u}{2} + P_u \delta_u \qquad \textbf{Eq. (8-24)}$$

where:

$$P_u = P_{uw} + P_{uf} \qquad \textbf{Eq. (8-25)}$$

The design strength for out-of-plane wall loading shall be in accordance with Eq. (8-26).

$$M_u \leq \phi\, M_n \qquad \textbf{Eq. (8-26)}$$

where:

$$M_n = (A_s f_y + P_u)\left(d - \frac{a}{2}\right) \qquad \textbf{Eq. (8-27)}$$

$$a = \frac{\left(P_u + A_s f_y\right)}{0.80 f'_m\, b} \qquad \textbf{Eq. (8-28)}$$

The nominal shear strength shall be determined by Section 8.2.4.1.2.

8.2.5.5 **Walls with factored axial stress greater than 0.05 f'_m.** The procedures set forth in this section shall be used for the design of masonry walls when the factored axial load stress at the location of maximum moment exceeds $0.05\, f'_m$. These provisions shall not be applied to walls with factored axial load stress equal to or exceeding $0.2\, f'_m$ or slenderness ratios exceeding 30. Such walls shall be designed in accordance with the provisions of Section 8.2.5.4 and shall have a minimum nominal thickness of 150 mm.

The nominal shear strength shall be determined by Section 8.2.4.1.2.

8.2.5.6 **Deflection design**. The horizontal midheight deflection, δ_s, under service lateral and service axial loads (without load factors) shall be limited by the relation:

$$\delta_s \leq 0.007\, h \qquad \textbf{Eq. (8-29)}$$

P-delta effects shall be included in deflection calculation. The midheight deflection shall be computed using either Eq. (8-30) or Eq. (8-31), as applicable.

(a) Where $M_{ser} < M_{cr}$

$$\delta_s = \frac{5 M_{ser} h^2}{48 E_m I_g} \text{ For } M_{ser} \leq M_{cr} \qquad \textbf{Eq. (8-30)}$$

(b) Where $M_{cr} < M_{ser} < M_n$

$$\delta_s = \frac{5M_{cr}h^2}{48E_m l_g} + \frac{5(M_{ser} - M_{cr})h^2}{48E_m l_{cr}}$$ **Eq. (8-31)**

The cracking moment strength of the wall shall be computed using Eq. (8-32):

$$M_{cr} = S_n f_r$$ **Eq. (8-32)**

The modulus of rupture, f_r, shall be taken from Table 8.1.1.

8.2.6 **Wall design for in-plane loads**

8.2.6.1 **Scope.** The requirements of Section 8.2.6 are for the design of walls to resist in-plane loads.

8.2.6.2 **Reinforcement.** Reinforcement shall be in accordance with the following:

(a) The amount of vertical reinforcement shall not be less than one-half the horizontal reinforcement.

(b) The maximum reinforcement ratio shall be determined in accordance with Section 8.2.3.5.

8.2.6.3 **Flexural and axial strength.** The nominal flexural and axial strength shall be determined in accordance with Section 8.2.4.1.1.

8.2.6.4 **Shear strength.** The nominal shear strength shall be computed in accordance with Section 8.2.4.1.2.

SECTION 8.3
UNREINFORCED (PLAIN) MASONRY

8.3.1 **Scope.** The requirements of Section 8.3 are in addition to the requirements of Section 8.1 and govern masonry design in which masonry is used to resist tensile forces.

8.3.1.1 **Strength for resisting loads.** Unreinforced (plain) masonry members shall be designed using the strength of masonry units, mortar, and grout in resisting design loads.

8.3.1.2 **Strength contribution from reinforcement.** Stresses in reinforcement shall not be considered effective in resisting design loads.

8.3.1.3 **Design criteria**. Unreinforced (plain) masonry members shall be designed to remain uncracked.

8.3.2 **Flexural strength of unreinforced (plain) masonry members**. The following assumptions shall apply when determining the flexural strength of unreinforced (plain) masonry members:

(a) Strength design of members for factored flexure and axial load shall be in accordance with principles of engineering mechanics.

(b) Strain in masonry shall be directly proportional to the distance from the neutral axis.

(c) Flexural tension in masonry shall be assumed to be directly proportional to strain.

(d) Flexural compressive stress in combination with axial compressive stress in masonry shall be assumed directly proportional to strain. Nominal compressive strength shall not exceed a stress corresponding to $0.80\, f'_m$.

(e) The nominal flexural tensile strength of masonry shall be determined from Section 8.1.7.2.

8.3.3 **Nominal axial strength of unreinforced (plain) masonry members.** Nominal axial strength, P_n, shall be computed using Eq. (8-33) or Eq. (8-34).

(a) For members having an h/r ratio not greater than 99:

$$P_n = 0.80\left(0.80 A_n\ f'_m\left[1-\left(\frac{h}{140r}\right)^2\right]\right) \quad \text{for } \frac{h}{r} \le 99 \qquad \textbf{Eq. (8-33)}$$

(b) For members having an h/r ratio greater than 99:

$$P_n = 0.80\left(0.80 A_n\ f'_m\left(\frac{70r}{h}\right)^2\right) \quad \text{for } \frac{h}{r} > 99 \qquad \textbf{Eq. (8-34)}$$

8.3.4 **Nominal shear strength** – Nominal shear strength, V_n, shall be the smallest of the following:

(a) $0.375\, A_n \sqrt{f'_m}$

(b) $0.83\, A_n$

(c) For running bond masonry not solidly grouted;

$0.26\, A_n + 0.3\, N_v$

(d) For stack bond masonry with open end units and grouted solid;

$0.26\, A_n + 0.3\, N_v$

(e) For running bond masonry grouted solid;

$0.414\, A_n + 0.3\, N_v$

(f) For stack bond other than open end units grouted solid.

$0.103 A_n$

CHAPTER 9
EMPIRICAL DESIGN OF MASONRY

SECTION 9.1
GENERAL

9.1.0 Empirically designed masonry shall conform to this chapter. The provisions of Chapter 1 through Chapter 5, excluding Sections 1.3(item 5), 1.3(item 6), 1.4, 3.12, 3.13, 5.2, shall apply to empirical design.

9.1.1 **Limitations.** Empirical masonry design shall not be utilized for any of the following conditions:

1. The design or construction of masonry in buildings assigned to Seismic Design Category D, as specified in SBC 301, and the design of the seismic-force-resisting system for buildings assigned to Seismic Design Category B or C.
2. The design or construction of masonry structures located in areas where the 3-second gust wind speed exceeds 145 km/hr.
3. Buildings more than 10700 mm in height which have masonry wall lateral-force-resisting systems.
4. Glass unit masonry.

In buildings that exceed one or more of the above limitations, masonry shall be designed in accordance with the engineered design provisions of Chapter 7 or Chapter 8, or the foundation wall provisions of Foundation Walls (SBC 303).

SECTION 9.2
LATERAL STABILITY

9.2.1 **Shear walls.** Where the structure depends upon masonry walls for lateral stability, shear walls shall be provided parallel to the direction of the lateral forces resisted.

9.2.1.1 **Shear wall thickness.** Minimum nominal thickness of masonry shear walls shall be 200 mm.

Exception: Shear walls of one-story buildings are permitted to be a minimum nominal thickness of 150 mm.

9.2.1.2 **Cumulative length of shear walls.** In each direction in which shear walls are required for lateral stability, shear walls shall be positioned in two separate planes. The minimum cumulative length of shear walls provided shall be 0.4 times the long dimension of the building. Cumulative length of shear walls shall not include openings or any element whose length is less than one-half its height.

9.2.1.3 **Maximum diaphragm ratio.** Masonry shear walls shall be spaced so that the length-to-width ratio of each diaphragm transferring lateral forces to the shear walls does not exceed the values given in Table 9.2.1.

TABLE 9.2.1
DIAPHRAGM LENGTH-TO-WIDTH RATIOS

FLOOR OR ROOF DIAPHRAGM CONSTRUCTION	MAXIMUM LENGTH-TO-WIDTH RATIO OF DIAPHRAGM PANEL*
Cast-in-place concrete	5:1
Precast concrete	4:1
Metal deck with concrete fill	3:1
Metal deck with no fill	2:1

* Diaphram Panel length: Dimension perpendicular to the resisting shear wall.
Diaphram Panel width: Dimension parallel to the resisting shear wall.

9.2.2 **Roofs.** The roof construction shall be designed so as not to impart out-of-plane lateral thrust to the walls under roof gravity load.

9.2.3 **Surface-bonded walls.** Dry-stacked, surface-bonded concrete masonry walls shall comply with the requirements of this code for masonry wall construction, except where otherwise noted.

9.2.3.1 **Strength.** Dry-stacked, surface-bonded concrete masonry walls shall be of adequate strength and proportions to support all superimposed loads without exceeding the allowable stresses listed in Table 9.2.2.

TABLE 9.2.2
ALLOWABLE STRESS GROSS CROSS-SECTIONAL AREA FOR DRY-STACKED, SURFACE-BONDED CONCRETE MASONRY WALLS

DESCRIPTION	MAXIMUM ALLOWABLE STRESS kPa
Compression standard block	310
Shear	70
Flexural tension	
Vertical span	124
Horizontal span	207

9.2.3.2 **Construction.** Construction of dry-stacked, surface-bonded masonry walls, including stacking and leveling of units, mixing and application of mortar and curing and protection shall comply with ASTM C 946.

SECTION 9.3
COMPRESSIVE STRESS REQUIREMENTS

9.3.1 **Calculations.** Compressive stresses in masonry due to vertical dead plus live loads, excluding wind or seismic loads, shall be determined in accordance with Section 9.3.2.

9.3.1.1 Dead and live loads shall be in accordance with SBC 301 with live load reductions as permitted in SBC 301.

9.3.2 **Allowable compressive stresses.** The compressive stresses in masonry shall not exceed the values given in Table 9.3.1. Stress shall be calculated based on specified rather than nominal dimensions.

TABLE 9.3.1
ALLOWABLE COMPRESSIVE STRESSES FOR EMPIRICAL DESIGN OF MASONRY

Construction; Compressive Strength of Unit Gross Area MPa	Allowable compressive stresses[a] gross cross-sectional area, MPa	
	Type M or S mortar	Type N mortar
Solid masonry of brick and other solid units of clay or shale; sand-lime or concrete brick:		
56 or greater	2.5	2
31	1.6	1.4
17.5	1.1	1.0
10.5	0.8	0.7
Grouted masonry, of clay or shale; sand-lime or concrete:		
31 or greater	1.6	1.4
17.5	1.1	1.0
10.5	0.8	0.7
Solid masonry of solid concrete masonry units:		
21 or greater	1.6	1.4
14	1.1	1.0
8.5	0.8	0.7
Masonry of hollow load-bearing units:		
14 or greater	1.0	0.8
10.5	0.8	0.7
7.0	0.5	0.5
5.0	0.4	0.4
Hollow walls (noncomposite masonry bonded)[b]		
Solid units:		
17.5 or greater	1.1	1.0
10.5	0.8	0.7
Hollow units	0.5	0.4
Stone ashlar masonry:		
Granite	5.0	4.5
Limestone or marble	3.0	2.8
Sandstone or cast stone	2.5	2.2
Rubble stone masonry		
Coursed, rough or random	0.8	0.7

a. Linear interpolation for determining allowable stresses for masonry units having compressive strengths which are intermediate between those given in the table is permitted.

b. Where floor and roof loads are carried upon one wythe, the gross cross-sectional area is that of the wythe under load; if both wythes are loaded, the gross cross-sectional area is that of the wall minus the area of the cavity between the wythes. Walls bonded with metal ties shall be considered as noncomposite walls unless collar joints are filled with mortar or grout.

9.3.2.1 **Calculated compressive stresses.** Calculated compressive stresses for single wythe walls and for multiwythe composite masonry walls shall be determined by dividing the design load by the gross cross-sectional area of the member. The area of openings, chases or recesses in walls shall not be included in the gross cross-sectional area of the wall.

9.3.2.2 **Multiwythe walls.** The allowable stress shall be as given in Table 9.3.1 for the weakest combination of the units used in each wythe.

SECTION 9.4
LATERAL SUPPORT

9.4.1 **Intervals.** Masonry walls shall be laterally supported in either the horizontal or vertical direction at intervals not exceeding those given in Table 9.4.1.

TABLE 9.4.1
WALL LATERAL SUPPORT REQUIREMENTS

Construction	Maximum Wall Length to Thickness or Wall Height to Thickness (Ratio)
Bearing walls	
Solid units or fully grouted	20
All others	18
Nonbearing walls	
Exterior	18
Interior	36

9.4.2 **Thickness.** Except for cavity walls and cantilever walls, the thickness of a wall shall be its nominal thickness measured perpendicular to the face of the wall. For cavity walls, the thickness shall be determined as the sum of the nominal thicknesses of the individual wythes. For cantilever walls, except for parapets, the ratio of height-to-nominal thickness shall not exceed six for solid masonry or four for hollow masonry. For parapets, see Section 9.5.5.

In computing the ratio for multiwythe walls, use the following thickness:

1. The nominal wall thickness for solid walls and for hollow walls bonded with masonry headers Section 9.6.2.
2. The sum of the nominal thicknesses of the wythes for non-composite walls connected with wall ties Section 9.6.3.

9.4.3 **Support elements.** Lateral support shall be provided by cross walls, pilasters, buttresses or structural frame members when the limiting distance is taken horizontally, or by floors, roofs acting as diaphragms or structural frame members when the limiting distance is taken vertically.

SECTION 9.5
THICKNESS OF MASONRY

9.5.0 Minimum thickness requirements shall be based on nominal dimensions of masonry.

9.5.1 **Thickness of walls.** The thickness of masonry walls shall conform to the requirements of Section 9.5.

9.5.2 **Minimum thickness.** The minimum thickness of masonry bearing walls more than one story high shall be 200 mm. Bearing walls of one-story buildings shall not be less than 150 mm thick.

9.5.3 **Rubble stone walls.** The minimum thickness of rough or random or coursed rubble stone walls shall be 400 mm.

9.5.4 **Change in thickness.** Where walls of masonry of hollow units or masonry bonded hollow walls are decreased in thickness, a course or courses of solid masonry shall be interposed between the wall below and the thinner wall above, or special units or

construction shall be used to transmit the loads from face shells or wythes above to those below.

9.5.5 Parapet walls

9.5.5.1 **Minimum thickness.** Unreinforced parapet walls shall be at least 200 mm thick, and their height shall not exceed three times their thickness.

9.5.5.2 **Additional provisions.** Additional provisions for parapet walls are contained in Flashing and Coping (Roof Assemblies and Rooftop Structures).

9.5.5.3 **Reinforcement.** Parapet walls shall be reinforced. The reinforcement shall be secured to slabs.

9.5.6 **Foundation walls.** Foundation walls shall comply with the requirements of Sections 9.5.6.1 and 9.5.6.2.

9.5.6.1 **Minimum thickness.** Minimum thickness for foundation walls shall comply with the requirements of Table 9.5.1. The provisions of Table 9.5.1 are only applicable where the following conditions are met:

1. The foundation wall does not exceed 2400 mm in height between lateral supports,
2. The terrain surrounding foundation walls is graded to drain surface water away from foundation walls,
3. Backfill is drained to remove ground water away from foundation walls,
4. Lateral support is provided at the top of foundation walls prior to backfilling,
5. The length of foundation walls between perpendicular masonry walls or pilasters is a maximum of three times the basement wall height,
6. The backfill is granular and soil conditions in the area are nonexpansive, and
7. Masonry is laid in running bond using Type M or S mortar.

9.5.6.2 **Design requirements.** Where the requirements of Section 9.5.6.1 are not met, foundation walls shall be designed in accordance with SBC 303.

TABLE 9.5.1
FOUNDATION WALL CONSTRUCTION

Wall Construction	Nominal Wall Thickness mm	Maximum Depth of Unbalanced Backfill m
Hollow unit masonry	200 250 300	1.50 1.80 2.10
Solid unit masonry	200 250 300	1.50 2.10 2.10
Fully grouted masonry	200 250 300	2.10 2.50 2.50

SECTION 9.6
BOND

9.6.1 **General.** The facing and backing of multiwythe masonry walls shall be bonded in accordance with Section 9.6.2, 9.6.3 or 9.6.4.

9.6.2 **Bonding with masonry headers.**

9.6.2.1 **Solid units.** Where the facing and backing (adjacent wythes) of solid masonry construction are bonded by means of masonry headers, no less than 4 percent of the wall surface of each face shall be composed of headers extending not less than 75 mm into the backing. The distance between adjacent full-length headers shall not exceed 600 mm either vertically or horizontally. In walls in which a single header does not extend through the wall, headers from the opposite sides shall overlap at least 75 mm, or headers from opposite sides shall be covered with another header course overlapping the header below at least 75 mm.

9.6.2.2 **Hollow units.** Where two or more hollow units are used to make up the thickness of a wall, the stretcher courses shall be bonded at vertical intervals not exceeding 860 mm by lapping at least 75 mm over the unit below, or by lapping at vertical intervals not exceeding 400 mm with units that are at least 50 percent greater in thickness than the units below.

9.6.2.3 **Masonry bonded hollow walls.** In masonry bonded hollow walls, the facing and backing shall be bonded so that not less than 4 percent of the wall surface of each face is composed of masonry bonded units extending not less than 75 mm into the backing. The distance between adjacent bonders shall not exceed 600 mm either vertically or horizontally.

9.6.3 **Bonding with wall ties or joint reinforcement.**

9.6.3.1 **Bonding with wall ties.** Except as required by Section 9.6.3.1.1, where the facing and backing (adjacent wythes) of masonry walls are bonded with wire size (WD 5) wall ties or metal wire of equivalent stiffness embedded in the horizontal mortar joints, there shall be at least one metal tie for each 0.42 m^2 of wall area. The maximum vertical distance between ties shall not exceed 600 mm, and the maximum horizontal distance shall not exceed 900 mm. Rods or ties bent to rectangular shape shall be used with hollow masonry units laid with the cells vertical. In other walls, the ends of ties shall be bent to 1.5 rad angles to provide hooks no less than 50 mm long. Wall ties shall be without drips. Additional bonding ties shall be provided at all openings spaced not more than 900 mm apart around the perimeter and within 300 mm of the opening.

9.6.3.1.1 **Bonding with adjustable wall ties.** Where the facing and backing (adjacent wythes) of masonry are bonded with adjustable wall ties, there shall be at least one tie for each 0.16 m^2 of wall area. Neither the vertical nor horizontal spacing of the adjustable wall ties shall exceed 400 mm. The maximum vertical offset of bed joints from one wythe to the other shall be 30 mm. The maximum clearance between connecting parts of the ties shall be 1.6 mm. When pintle legs are used, ties shall have at least two wire size (WD 5) legs.

9.6.3.2 **Bonding with prefabricated joint reinforcement.** Where the facing and backing (adjacent wythes) of masonry are bonded with prefabricated joint reinforcement, there shall be at least one cross wire serving as a tie for each 0.25 m^2 of wall area. The vertical spacing of the joint reinforcing shall not exceed 600 mm. Cross wires

on prefabricated joint reinforcement shall not be less than (WD 4) and shall be without drips. The longitudinal wires shall be embedded in the mortar.

9.6.4 Bonding with natural or cast stone.

9.6.4.1 Ashlar masonry. In ashlar masonry, bonder units, uniformly distributed, shall be provided to the extent of not less than 10 percent of the wall area. Such bonder units shall extend not less than 100 mm into the backing wall.

9.6.4.2 Rubble stone masonry. Rubble stone masonry 600 mm or less in thickness shall have bonder units with a maximum spacing of 900 mm vertically and 900 mm horizontally, and if the masonry is of greater thickness than 600 mm, shall have one bonder unit for each 0.5 m^2 of wall surface on both sides.

9.6.5 Masonry bonding pattern.

9.6.5.1 Masonry laid in running bond. Each wythe of masonry shall be laid in running bond, head joints in successive courses shall be offset by not less than one-fourth the unit length or the masonry walls shall be reinforced longitudinally as required in Section 9.6.5.2.

9.6.5.2 Masonry laid in stack bond. Where unit masonry is laid with less head joint offset than in Section 9.6.5.1, the minimum area of horizontal reinforcement placed in mortar bed joints or in bond beams spaced not more than 1200 mm apart, shall be 0.0003 times the vertical cross-sectional area of the wall.

SECTION 9.7
ANCHORAGE

9.7.1 General. Masonry elements shall be anchored in accordance with Section 9.7.2 through 9.7.4.

9.7.2 Intersecting walls. Masonry walls depending upon one another for lateral support shall be anchored or bonded at locations where they meet or intersect by one of the methods indicated in Sections 9.7.2.1 through 9.7.2.5.

9.7.2.1 Bonding pattern. Fifty percent of the units at the intersection shall be laid in an overlapping masonry bonding pattern, with alternate units having a bearing of not less than 75 mm on the unit below.

9.7.2.2 Steel connectors. Walls shall be anchored by steel connectors having a minimum section of 6 mm by 40 mm, with ends bent up at least 50 mm or with cross pins to form anchorage. Such anchors shall be at least 600 mm long and the maximum spacing shall be 1200 mm.

9.7.2.3 Joint reinforcement. Walls shall be anchored by joint reinforcement spaced at a maximum distance of 200 mm. Longitudinal wires of such reinforcement shall be at least wire size (WD 4) and shall extend at least 800 mm in each direction at the intersection.

9.7.2.4 Interior nonload-bearing walls. Interior nonload-bearing walls shall be anchored at their intersection, at vertical intervals of not more than 400 mm with joint reinforcement or 6.5 mm mesh galvanized hardware cloth.

9.7.2.5 Ties, joint reinforcement or anchors. Other metal ties, joint reinforcement or anchors, if used, shall be spaced to provide equivalent area of anchorage to that required by this section.

9.7.3 **Floor and roof anchorage.** Floor and roof diaphragms providing lateral support to masonry shall comply with the live loads in Uniform Live Loads (Structural Design) and shall be connected to the masonry in accordance with Section 9.7.3.1 through 9.7.3.3.

9.7.3.1 **Steel floor joists.** Steel floor joists bearing on masonry walls shall be anchored to the wall with 10 mm round bars, or their equivalent, spaced not more than 1800 mm o.c. Where joists are parallel to the wall, anchors shall be located at joist bridging.

9.7.3.2 **Roof diaphragms.** Roof diaphragms shall be anchored to masonry walls with 13 mm bolts, 1800 mm o.c. or their equivalent. Bolts shall extend and be embedded at least 400 mm into the masonry, or be hooked or welded to not less than 130 mm^2 of bond beam reinforcement placed not less than 150 mm from the top of the wall.

9.7.4 **Walls adjoining structural framing.** Where walls are dependent upon the structural frame for lateral support, they shall be anchored to the structural members with metal anchors or otherwise keyed to the structural members. Metal anchors shall consist of 13 mm bolts spaced at 1200 mm o.c. embedded 100 mm into the masonry, or their equivalent area.

SECTION 9.8
ADOBE CONSTRUCTION

9.8.0 Adobe construction shall comply with this section and shall be subject to the requirements of this code.

9.8.1 **Unstabilized adobe.**

9.8.1.1 **Compressive strength.** Adobe units shall have an average compressive strength of 2000 kPa when tested in accordance with ASTM C 67. Five samples shall be tested and no individual unit is permitted to have a compressive strength of less than 1750 kPa.

9.8.1.2 **Modulus of rupture.** Adobe units shall have an average modulus of rupture of 350 kPa when tested in accordance with the following procedure. Five samples shall be tested and no individual unit shall have a modulus of rupture of less than 240 kPa.

9.8.1.2.1 **Support conditions.** A cured unit shall be simply supported by 50 mm cylindrical supports located 50 mm in from each end and extending the full width of the unit.

9.8.1.2.2 **Loading conditions.** A 50 mm cylinder shall be placed at midspan parallel to the supports.

9.8.1.2.3 **Testing procedure.** A vertical load shall be applied to the cylinder at the rate of 37 N/s until failure occurs.

9.8.1.2.4 **Modulus of rupture determination.** The modulus of rupture shall be determined by the equation:

$$f_r = 3WL_s / 2bt^2 \qquad \textbf{Eq. (9-1)}$$

where, for the purposes of this section only:

b = Width of the test specimen measured parallel to the loading cylinder, mm.

f_r = Modulus of rupture, MPa.

L_s = Distance between supports, mm.

t = Thickness of the test specimen measured parallel to the direction of load, mm.

W = The applied load at failure, N.

9.8.1.3 **Moisture content requirements.** Adobe units shall have a moisture content not exceeding 4 percent by weight.

9.8.1.4 **Shrinkage cracks.** Adobe units shall not contain more than three shrinkage cracks and any single shrinkage crack shall not exceed 75 mm in length or 3.0 mm in width.

9.8.2 **Stabilized adobe.**

9.8.2.1 **Material requirements.** Stabilized adobe shall comply with the material requirements of unstabilized adobe in addition to Section 9.8.2.1.1 and 9.8.2.1.2.

9.8.2.1.1 **Soil requirements.** Soil used for stabilized adobe units shall be chemically compatible with the stabilizing material.

9.8.2.1.2 **Absorption requirements.** A 100 mm cube, cut from a stabilized adobe unit dried to a constant weight in a ventilated oven at 100 °C to 115 °C, shall not absorb more than 2-1/2% moisture by weight when placed upon a constantly water-saturated, porous surface for seven days. A minimum of five specimens shall be tested and each specimen shall be cut from a separate unit.

9.8.3 **Working stress.** The allowable compressive stress based on gross cross-sectional area of adobe shall not exceed 200 kPa.

9.8.3.1 **Bolts.** Bolt values shall not exceed those set forth in Table 9.8.1.

TABLE 9.8.1
ALLOWABLE SHEAR ON BOLTS IN ADOBE MASONRY

Diameter of Bolts mm	Minimum Embedment mm	Shear N
14	–	–
16	300	900
20	400	1400
22	500	1800
26	550	2250
30	600	2700

9.8.4 **Construction.**

9.8.4.1 **General.**

9.8.4.1.1 **Height restrictions.** Adobe construction shall be limited to buildings not exceeding one story, except that two-story construction is allowed when designed by a registered design professional.

9.8.4.1.2 **Mortar restrictions.** Mortar for stabilized adobe units shall comply with this Code or adobe soil. Adobe soil used as mortar shall comply with material requirements for stabilized adobe. Mortar for unstabilized adobe shall be Portland cement mortar.

9.8.4.1.3 **Mortar joints.** Adobe units shall be laid with full head and bed joints and in full running bond.

9.8.4.1.4 **Parapet walls.** Parapet walls constructed of adobe units shall be waterproofed.

9.8.4.2 **Wall thickness.** The minimum thickness of exterior walls in one-story buildings shall be 250 mm. The walls shall be laterally supported at intervals not exceeding 7000 mm. The minimum thickness of interior load-bearing walls shall be 200 mm. In no case shall the unsupported height of any wall constructed of adobe units exceed 10 times the thickness of such wall.

9.8.4.3 **Foundations.**

9.8.4.3.1 **Foundation support.** Walls and partitions constructed of adobe units shall be supported by foundations or footings that extend not less than 150 mm above adjacent ground surfaces and are constructed of solid masonry (excluding adobe) or concrete. Footings and foundations shall comply with SBC 303.

9.8.4.3.2 **Lower course requirements.** Stabilized adobe units shall be used in adobe walls for the first 100 mm above the finished first-floor elevation.

9.8.4.4 **Isolated piers or columns.** Adobe units shall not be used for isolated piers or columns in a load-bearing capacity. Walls less than 600 mm in length shall be considered isolated piers or columns.

9.8.4.5 **Tie beams.** Exterior walls and interior load-bearing walls constructed of adobe units shall have a continuous tie beam at the level of the floor or roof bearing and meeting the following requirements.

9.8.4.5.1 **Concrete tie beams.** Concrete tie beams shall be a minimum depth of 150 mm and a minimum width of 250 mm. Concrete tie beams shall be continuously reinforced with a minimum of two Dia 12 mm reinforcing bars. The ultimate compressive strength of concrete shall be at least 20 MPa at 28 days.

9.8.4.6 **Exterior finish.** Exterior walls constructed of unstabilized adobe units shall have their exterior surface covered with a minimum of two coats of Portland cement plaster having a minimum thickness of 20 mm and conforming to ANSI A42.2. Lathing shall comply with ANSI A42.3. Fasteners shall be spaced at 400 mm o.c. maximum. Exposed wood surfaces shall be treated with an approved wood preservative or other protective coating prior to lath application.

SECTION 9.9
MISCELLANEOUS REQUIREMENT

9.9.1 **Chases and recesses.** Masonry directly above chases or recesses wider than 300 mm shall be supported on lintels.

9.9.2 **Lintels.** Lintels shall be considered structural members and shall be designed in accordance with the applicable provisions of SBC 301.

9.9.3 **Support on wood.** No masonry shall be supported on wood girders or other forms of wood construction.

9.9.4 **Corbelling.** Solid masonry units shall be used for corbelling. The maximum corbelled projection beyond the face of the wall shall be not more than one-half of the wall thickness or one-half the wythe thickness for hollow walls; the maximum projection of one unit shall neither exceed one-half the height of the unit nor one-third its thickness at right angles to the wall.

CHAPTER 10
GLASS UNIT MASONRY

SECTION 10.1

10.1.0 This section covers the empirical requirements for nonload-bearing glass unit masonry elements in exterior or interior walls.

The provisions of Chapter 1 through Chapter 4, excluding Section 1.3 (5 to 6), 3.12, 3.13 shall apply to design and construction of glass unit masonry, except as stated herein. Section (5.2) shall not apply to construction of glass unit masonry.

10.1.1 **Limitations.** Solid or hollow approved glass block shall not be used in fire walls, party walls, fire barriers or fire partitions, or for load-bearing construction. Such blocks shall be erected with mortar and reinforcement in metal channel-type frames, structural frames, masonry or concrete recesses, embedded panel anchors as provided for both exterior and interior walls or other approved joint materials. Wood strip framing shall not be used in walls required to have a fire-resistance rating by other provisions of SBC.

Exceptions:

1. Glass-block assemblies having a fire protection rating of not less than $3/4$ hour shall be permitted as opening protectives in accordance with Chapter 4 SBC 801 in barriers and fire partitions that have a required fire-resistance rating of 1 hour or less and do not enclose exit stairways or exit passageways.
2. Glass-block assemblies as permitted in Section 2.16.5, SBC 201.

SECTION 10.2
UNITS

10.2.0 Hollow or solid glass-block units shall be standard or thin units.

10.2.1 **Standard units.** The specified thickness of standard units shall be 100 mm.

10.2.2 **Thin units.** The specified thickness of thin units shall be 80 mm for hollow units or 75 mm for solid units.

SECTION 10.3
PANEL SIZE

10.3.1 **Exterior standard-unit panels.** The maximum area of each individual exterior standard-unit panel shall be 13 m^2 when the design wind pressure is 960 N/m^2. The maximum panel dimension between structural supports shall be 7500 mm in width or 6000 mm in height. The panel areas are permitted to be adjusted in accordance with Figure 10.3.1 for other wind pressures.

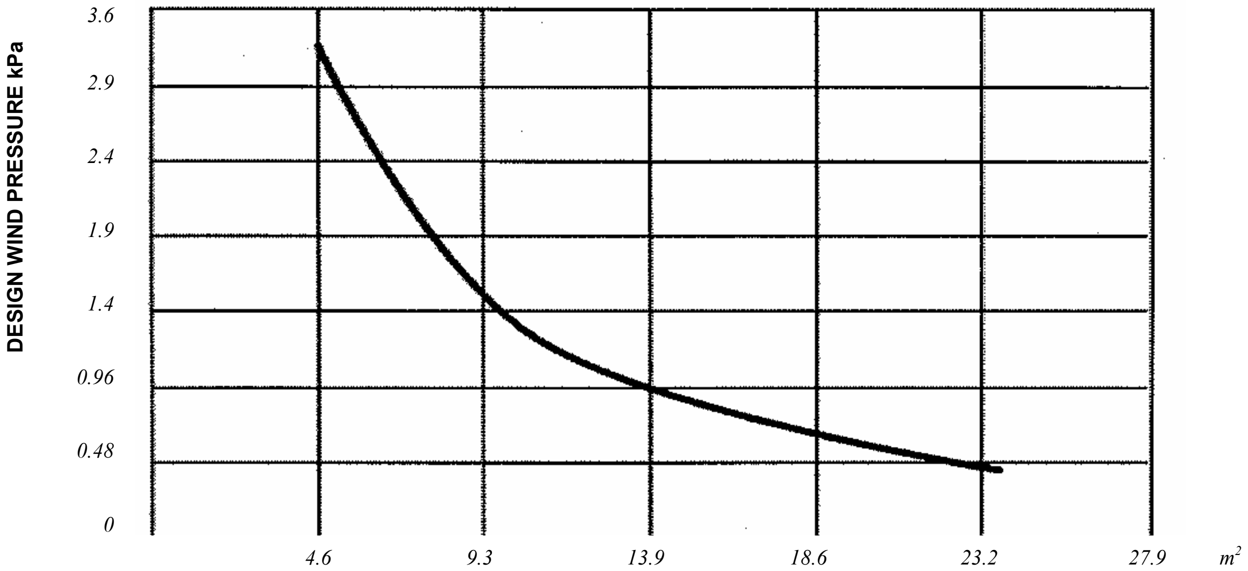

Figure 10.3.1
Glass Masonry Design Wind Load Resistance

10.3.2 **Exterior thin-unit panels.** The maximum area of each individual exterior thin-unit panel shall be 8 m^2. The maximum dimension between structural supports shall be 4500 mm in width or 3000 mm in eight. Thin units shall not be used in applications where the design wind pressure exceeds 950 N/m^2.

10.3.3 **Interior panels.** The maximum area of each individual standard-unit panel shall be 23 m^2. The maximum area of each thin-unit panel shall be 14 m^2. The maximum dimension between structural supports shall be 7600 mm in width or 6000 mm in height.

10.3.4 **Solid units.** The maximum area of solid glass-block wall panels in both exterior and interior walls shall not be more than 9 m^2.

10.3.5 **Curved panels.** The width of curved panels shall conform to the requirements of Section 10.3.1, 10.3.2 and 10.3.3, except additional structural supports shall be provided at locations where a curved section joins a straight section, and at inflection points in multi-curved walls.

SECTION 10.4
SUPPORT

10.4.1 **Isolation.** Glass unit masonry panels shall be isolated so that in-plane loads are not imparted to the panel.

10.4.2 **Vertical.** Maximum total deflection of structural members supporting glass unit masonry shall not exceed $l/600$.

10.4.3 **Lateral.** Glass unit masonry panels more than one unit wide or one unit high shall be laterally supported along their tops and sides. Lateral support shall be provided by panel anchors along the top and sides spaced not more than 400 mm o.c. or by channel-type restraints. Glass unit masonry panels shall be recessed at least 25

mm within channels and chases. Channel-type restraints shall be oversized to accommodate expansion material in the opening and packing and sealant between the framing restraints and the glass unit masonry perimeter units. Lateral supports for glass unit masonry panels shall be designed to resist applied loads, or a minimum of 3000 N/m (of panel), whichever is greater.

Exceptions:

1. Lateral support at the top of glass unit masonry panels that are no more than one unit wide shall not be required.
2. Lateral support at the sides of glass unit masonry panels that are no more than one unit high shall not be required.

10.4.3.1 **Single unit panels.** Single unit glass unit masonry panels shall conform to the requirements of Section 10.4.3, except lateral support shall not be provided by panel anchors.

SECTION 10.5
EXPANSION JOINTS

10.5.0 Glass unit masonry panels shall be provided with expansion joints along the top and sides at all structural supports. Expansion joints shall have sufficient thickness to accommodate displacements of the supporting structure, but shall not be less than 10 mm in thickness. Expansion joints shall be entirely free of mortar or other debris and shall be filled with resilient material. The sills of glass-block panels shall be coated with approved water-based asphaltic emulsion, or other elastic waterproofing material, prior to laying the first mortar course.

SECTION 10.6
MORTAR

10.6.0 Mortar for glass unit masonry shall comply with Section 3.7.

SECTION 10.7
REINFORCEMENT

10.7.0 Glass unit masonry panels shall have horizontal joint reinforcement spaced not more than 400 mm on center, located in the mortar bed joint, and extending the entire length of the panel but not across expansion joints. Longitudinal wires shall be lapped a minimum of 150 mm at splices. Joint reinforcement shall be placed in the bed joint immediately below and above openings in the panel. The reinforcement shall have not less than two parallel longitudinal wires of size (WD 4), and have welded cross wires of size (WD 4).

CHAPTER 11
MASONRY FIREPLACES

SECTION 11.1
DEFINITION

11.1.0 A masonry fireplace is a fireplace constructed of masonry. Masonry fireplaces shall be constructed in accordance with this section, Table 11.1.1 and Figure 11.1.1.

SECTION 11.2
FOOTINGS AND FOUNDATIONS

11.2.0 Footings for masonry fireplaces and their chimneys shall be constructed of concrete or solid masonry at least 300 mm thick and shall extend at least 150 mm beyond the face of the fireplace or foundation wall on all sides. Footings shall be founded on natural undisturbed earth or engineered fill. Footings shall be at least 300 mm below finished grade.

11.2.1 **Ash dump cleanout.** Cleanout openings, located within foundation walls below fireboxes, when provided, shall be equipped with ferrous metal or masonry doors and frames constructed to remain tightly closed, except when in use. Cleanouts shall be accessible and located so that ash removal will not create a hazard to combustible materials.

SECTION 11.3
SEISMIC REINFORCING

11.3.0 Masonry fireplaces shall be constructed, anchored, supported and reinforced as required in this chapter. In Seismic Design Category A, B or C, reinforcement and seismic anchorage is not required. In Seismic Design Category D, masonry and concrete fireplaces shall be reinforced and anchored as detailed in Section 11.3.1, 11.3.2, 11.4 and 11.4.1 for chimneys serving fireplaces.

11.3.1 **Vertical reinforcing.** For fireplaces with chimneys up to 1000 mm wide, four Dia 12 mm continuous vertical bars, anchored in the foundation, shall be placed in the concrete, between wythes of solid masonry or within the cells of hollow unit masonry and grouted in accordance with Section 3.10. For fireplaces with chimneys greater than 1000 mm wide, two additional Dia 12 mm vertical bars shall be provided for each additional 1000 mm in width or fraction thereof.

11.3.2 **Horizontal reinforcing.** Vertical reinforcement shall be placed enclosed within 6 mm ties or other reinforcing of equivalent net cross-sectional area, placed in the bed joints of unit masonry at a minimum of every 450 mm of vertical height. Two such ties shall be provided at each bend in the vertical bars.

SECTION 11.4
SEISMIC ANCHORAGE

11.4.0 Masonry and concrete chimneys in Seismic Design Category D shall be anchored at each floor, ceiling or roof line more than 1800 mm above grade, except where constructed completely within the exterior walls. Anchorage shall conform to the following requirements.

11.4.1 **Anchorage.** Two 5 mm by 25 mm straps shall be embedded a minimum of 300 mm into the chimney. Straps shall be hooked around the outer bars and extend 150 mm beyond the bend. Each strap shall be fastened to a minimum of four floor joists with two 13 mm bolts.

SECTION 11.5
FIREBOX WALLS

11.5.0 Masonry fireboxes shall be constructed of solid masonry units, hollow masonry units grouted solid, stone or concrete. When a lining of firebrick at least 50 mm in thickness or other approved lining is provided, the minimum thickness of back and sidewalls shall each be 200 mm of solid masonry, including the lining. The width of joints between firebricks shall not be greater than 6.0 mm. When no lining is provided, the total minimum thickness of back and sidewalls shall be 250 mm of solid masonry. Firebrick shall conform to ASTM C 27 or ASTM C 1261 and shall be laid with medium-duty refractory mortar conforming to ASTM C 199.

11.5.1 **Steel fireplace units.** Steel fireplace units are permitted to be installed with solid masonry to form a masonry fireplace provided they are installed according to either the requirements of their listing or the requirements of this section. Steel fireplace units incorporating a steel firebox lining shall be constructed with steel not less than 6.0 mm in thickness, and an air-circulating chamber which is ducted to the interior of the building. The firebox lining shall be encased with solid masonry to provide a total thickness at the back and sides of not less than 200 mm, of which not less than 100 mm shall be of solid masonry or concrete. Circulating air ducts employed with steel fireplace units shall be constructed of metal or masonry.

SECTION 11.6
FIREBOX DIMENSIONS

11.6.0 The firebox of a concrete or masonry fireplace shall have a minimum depth of 500 mm. The throat shall not be less than 200 mm above the fireplace opening. The throat opening shall not be less than 100 mm in depth. The cross-sectional area of the passageway above the firebox, including the throat, damper and smoke chamber, shall not be less than the cross-sectional area of the flue.

Exception: Rumsford fireplaces shall be permitted provided that the depth of the fireplace is at least 300 mm and at least one-third of the width of the fireplace opening, and the throat is at least 300 mm above the lintel, and at least $1/20$ of the cross-sectional area of the fireplace opening.

TABLE 11.1.1
SUMMARY OF REQUIREMENTS FOR MASONRY FIREPLACES AND CHIMNEYS[a]

Item	Letter	Requirements	Section
Hearth and hearth extension thickness	A	100 mm minimum thickness for hearth, 50 mm minimum thickness for hearth extension.	11.9
Hearth extension (each side of opening)	B	200 mm for fireplace opening less than 0.6 m^2. 300 mm for fireplace opening greater than or equal to 0.6 m^2.	11.10
Hearth extension (front of opening)	C	400 mm for fireplace opening less than 0.6 m^2. 500 mm for fireplace opening greater than or equal to 0.6 m^2.	11.10
Firebox dimensions	–	500 mm minimum firebox depth. 300 mm minimum firebox depth for Rumford fireplaces.	11.6
Hearth and hearth extension reinforcing	D	Reinforced to carry its own weight and all imposed loads.	11.9
Thickness of wall of firebox	E	250 mm solid masonry or 200 mm where firebrick lining is used.	11.5
Distance from top of opening to throat	F	200 mm minimum.	11.7 11.7.1
Smoke chamber wall thickness dimensions	G	150 mm lined; 200 mm unlined. Not taller than opening width; walls not inclined more than 0.76 rad from vertical for prefabricated smoke chamber linings or 0.5 rad from vertical for corbeled masonry.	11.8
Chimney vertical reinforcing	H	Four Dia 12 mm full-length bars for chimney up to1000 mm wide. Add two Dia 12 mm bars for each additional 1000 mm or fraction of width, or for each additional flue.	11.3.1, 13.3.1
Chimney horizontal reinforcing	J	6 mm ties at each 450 mm, and two ties at each bend in vertical steel.	11.3.2 13.3.2
Fireplace lintel	L	Noncombustible material with 100 mm bearing length of each side of opening.	11.7
Chimney walls with flue lining	M	100 mm thick solid masonry with 16 mm fireclay liner or equivalent. 13 mm grout or airspace between fireclay liner and wall.	13.11.1
Effective flue area (based on area of fireplace opening and chimney)	P	See (13.16).	13.16
Clearances From chimney From fireplace From combustible trim or materials Above roof	R	 50 mm interior, 25 mm exterior or 300 mm from lining. 50 mm back or sides or 300 mm from lining. 150 mm from opening 900 mm above roof penetration, 600 mm above part of structure within 3000 mm.	 13.19 11.11 11.12 13.9
Anchorage strap Number required Embedment into chimney Fasten to Number of bolts	S	5 mm by 25 mm Two 300 mm hooked around outer bar with 150 mm extension. 4 joists Two 13 mm diameter.	 11.4 13.4.1
Footing Thickness Width	T	 300 mm minimum. 150 mm each side of fireplace wall.	 11.2

a. This table provides a summary of major requirements for the construction of masonry chimneys and fireplaces. Letter references are to Figure 11.1.1, which shows examples of typical construction. This table does not cover all requirements, nor does it cover all aspects of the indicated requirements. For the actual mandatory requirements of the code, see the indicated section of text.

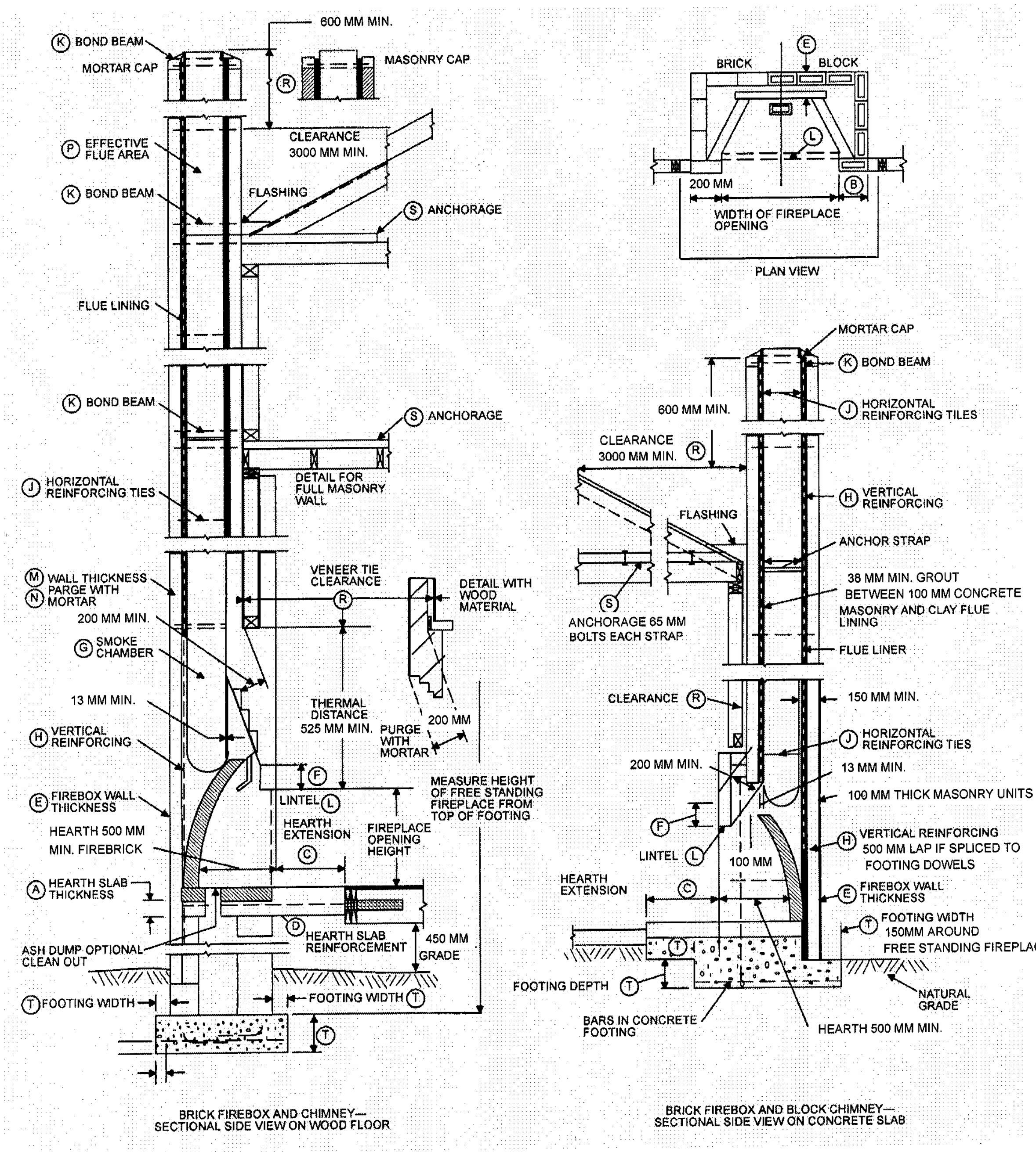

FIGURE 11.1.1

FIREPLACE AND CHIMNEY DETAILS

SECTION 11.7
LINTEL AND THROAT

11.7.0 Masonry over a fireplace opening shall be supported by a lintel of noncombustible material. The minimum required bearing length on each end of the fireplace opening shall be 100 mm. The fireplace throat or damper shall be located a minimum of 200 mm above the top of the fireplace opening.

11.7.1 **Damper.** Masonry fireplaces shall be equipped with a ferrous metal damper located at least 200 mm above the top of the fireplace opening. Dampers shall be

installed in the fireplace or at the top of the flue venting the fireplace, and shall be operable from the room containing the fireplace. Damper controls shall be permitted to be located in the fireplace.

SECTION 11.8
SMOKE CHAMBER WALLS

11.8.0 Smoke chamber walls shall be constructed of solid masonry units, hollow masonry units grouted solid, stone or concrete. Corbeling of masonry units shall not leave unit cores exposed to the inside of the smoke chamber. The inside surface of corbeled masonry shall be parged smooth. Where no lining is provided, the total minimum thickness of front, back and sidewalls shall be 200 mm of solid masonry. When a lining of firebrick at least 50 mm thick, or a lining of vitrified clay at least 16 mm thick, is provided, the total minimum thickness of front, back and sidewalls shall be 150 mm of solid masonry, including the lining. Firebrick shall conform to ASTM C 27 or ASTM C 1261 and shall be laid with refractory mortar conforming to ASTM C 199.

11.8.1 **Smoke chamber dimensions.** The inside height of the smoke chamber from the fireplace throat to the beginning of the flue shall not be greater than the inside width of the fireplace opening. The inside surface of the smoke chamber shall not be inclined more than 0.76 rad from vertical when prefabricated smoke chamber linings are used or when the smoke chamber walls are rolled or sloped rather than corbeled. When the inside surface of the smoke chamber is formed by corbeled masonry, the walls shall not be corbeled more than 0.5 rad from vertical.

SECTION 11.9
HEARTH AND HEARTH EXTENSION

11.9.0 Masonry fireplace hearths and hearth extensions shall be constructed of concrete or masonry, supported by noncombustible materials, and reinforced to carry their own weight and all imposed loads. No combustible material shall remain against the underside of hearths or hearth extensions after construction.

11.9.1 **Hearth thickness.** The minimum thickness of fireplace hearths shall be 100 mm.

11.9.2 **Hearth extension thickness.** The minimum thickness of hearth extensions shall be 50 mm.
Exception: When the bottom of the firebox opening is raised at least 200 mm above the top of the hearth extension, a hearth extension of not less than 10 mm brick, concrete, stone, tile or other approved noncombustible material is permitted.

SECTION 11.10
HEARTH EXTENSION DIMENSIONS

11.10.0 Hearth extensions shall extend at least 400 mm in front of, and at least 200 mm beyond, each side of the fireplace opening Where the fireplace opening is 0.6 m^2 or larger, the hearth extension shall extend at least 500 mm in front of, and at least 300 mm beyond, each side of the fireplace opening.

SECTION 11.11
FIREPLACE CLEARANCE

11.11.0 Any portion of a masonry fireplace located in the interior of a building or within the exterior wall of a building shall have a clearance to combustibles of not less than 50 mm from the front faces and sides of masonry fireplaces and not less than 100 mm from the back faces of masonry fireplaces. The airspace shall not be filled, except to provide fireblocking in accordance with Section 11.13.

Exceptions:

1. Masonry fireplaces listed and labeled for use in contact with combustibles in accordance with UL 127, and installed in accordance with the manufacturer's installation instructions, are permitted to have combustible material in contact with their exterior surfaces.
2. When masonry fireplaces are constructed as part of masonry or concrete walls, combustible materials shall not be in contact with the masonry or concrete walls less than 300 mm from the inside surface of the nearest firebox lining.
3. Exposed combustible trim and the edges of sheathing materials, such as wood siding, flooring and drywall, are permitted to abut the masonry fireplace sidewalls and hearth extension, in accordance with Figure 11.11.1, provided such combustible trim or sheathing is a minimum of 300 mm from the inside surface of the nearest firebox lining.
4. Exposed combustible mantels or trim is permitted to be placed directly on the masonry fireplace front surrounding the fireplace opening provided such combustible materials shall not be placed within 150 mm of a fireplace opening. Combustible material within 300 mm of the fireplace opening shall not project more than 3 mm for each 25 mm distance from such opening.

SECTION 11.12
MANTEL AND TRIM

11.12.0 Woodwork or other combustible materials shall not be placed within 150 mm of a fireplace opening. Combustible material within 300 mm of the fireplace opening shall not project more than 3 mm for each 25 mm distance from such opening.

SECTION 11.13
FIREPLACE FIREBLOCKING

11.13.0 All spaces between fireplaces and floors and ceilings through which fireplaces pass shall be fireblocked with noncombustible material securely fastened in place. The fireblocking of spaces between wood joists, beams or headers shall be to a depth of 25 mm and shall only be placed on strips of metal or metal lath laid across the spaces between combustible material and the chimney.

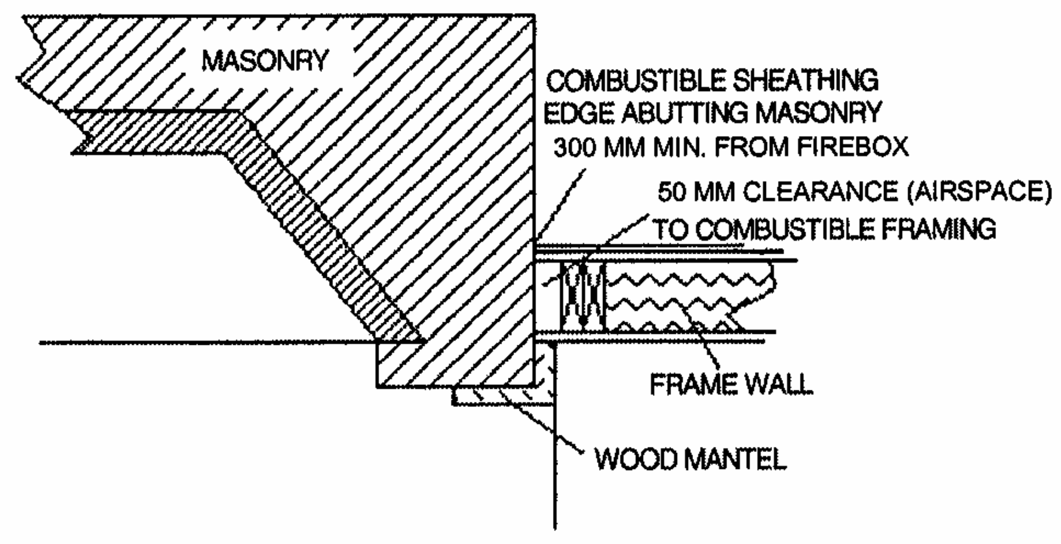

FIGURE 11.11.1
ILLUSTRATION OF EXCEPTION TO FIREPLACE CLEARANCE PROVISION

SECTION 11.14
EXTERIOR AIR

11.14.0 Factory-built or masonry fireplaces covered in this section shall be equipped with an exterior air supply to ensure proper fuel combustion unless the room is mechanically ventilated and controlled so that the indoor pressure is neutral or positive.

11.14.1 **Factory-built fireplaces.** Exterior combustion air ducts for factory-built fireplaces shall be listed components of the fireplace, and installed according to the fireplace manufacturer's instructions.

11.14.2 **Masonry fireplaces.** Listed combustion air ducts for masonry fireplaces shall be installed according to the terms of their listing and manufacturer's instructions.

11.14.3 **Exterior air intake.** The exterior air intake shall be capable of providing all combustion air from the exterior of the dwelling. The exterior air intake shall not be located within the garage, attic, basement or crawl space of the dwelling nor shall the air intake be located at an elevation higher than the firebox. The exterior air intake shall be covered with a corrosion-resistant screen of 6 mm mesh.

11.14.4 **Clearance.** Unlisted combustion air ducts shall be installed with a minimum 25 mm clearance to combustibles for all parts of the duct within 1500 mm of the duct outlet.

11.14.5 **Passageway.** The combustion air passageway shall be a minimum of 4000 mm^2 and not more than 0.04 m^2, except that combustion air systems for listed fireplaces or for fireplaces tested for emissions shall be constructed according to the fireplace manufacturer's instructions.

11.14.6 **Outlet.** The exterior air outlet is permitted to be located in the back or sides of the firebox chamber or within 600 mm of the firebox opening on or near the floor. The outlet shall be closable and designed to prevent burning material from dropping into concealed combustible spaces.

CHAPTER 12
MASONRY HEATERS

SECTION 12.1
DEFINITION

12.1.1 A masonry heater is a heating appliance constructed of concrete or solid masonry, hereinafter referred to as "masonry heater," having a mass of at least 800 kg, excluding the chimney and foundation, which is designed to absorb and store heat from a solid fuel fire built in the firebox by routing the exhaust gases through internal heat exchange channels in which the flow path downstream of the firebox includes at least one 3.14 rad change in flow direction before entering the chimney, and that delivers heat by radiation from the masonry surface of the heater that shall not exceed 110° C except within 203 mm surrounding the fuel loading door(s).

SECTION 12.2
INSTALLATION

12.2.1 Masonry heaters shall be listed or installed in accordance with ASTM E 1602.

SECTION 12.3
SEISMIC REINFORCING

12.3.1 Seismic reinforcing shall not be required within the body of a masonry heater whose height is equal to or less than 2.5 times its body width and where the masonry chimney serving the heater is not supported by the body of the heater. Where the masonry chimney shares a common wall with the facing of the masonry heater, the chimney portion of the structure shall be reinforced in accordance with Section 13.3 and 13.4.

SECTION 12.4
MASONRY HEATER CLEARANCE

12.4.1 Wood or other combustible framing shall not be placed within 100 mm of the outside surface of a masonry heater, provided the wall thickness of the firebox is not less than 200 mm and the wall thickness of the heat exchange channels is not less than 120 mm. A clearance of at least 200 mm shall be provided between the gas-tight capping slab of the heater and a combustible ceiling. The required space between the heater and combustible material shall be fully vented to permit the free flow of air around all heater surfaces.

CHAPTER 13
MASONRY CHIMNEYS

SECTION 13.1
GENERAL

13.1.0 A masonry chimney is a chimney constructed of masonry, hereinafter referred to as "masonry chimney." Masonry chimneys shall be constructed, anchored, supported and reinforced as required in this section.

13.1.1 **Design requirements.** Masonry chimneys shall be designed as load bearing in accordance with requirements of Chapter 1 through Chapter 8.

SECTION 13.2
FOOTINGS AND FOUNDATIONS

13.2.0 Foundations for masonry chimneys shall be constructed of concrete or solid masonry at least 300 mm thick and shall extend at least 150 mm beyond the face of the foundation or support wall on all sides. Footings shall be founded on natural undisturbed earth or engineered fill. In areas not subjected to freezing, footings shall be at least 300 mm below finished grade.

13.2.1 **Design requirements.** Footings and foundations shall be designed in accordance with SBC 303.

SECTION 13.3
SEISMIC REINFORCING

13.3.0 Masonry chimneys shall be constructed, anchored, supported and reinforced as required in this chapter. In Seismic Design Category A, B or C, reinforcement and seismic anchorage is not required. In Seismic Design Category D, masonry chimneys shall be reinforced and anchored as detailed in Section 13.3.1 and 13.3.2.

13.3.1 **Vertical reinforcing.** For chimneys up to 1000 mm wide, four Dia 12 mm continuous vertical bars anchored in the foundation shall be placed, between wythes of solid masonry or within the cells of hollow unit masonry and grouted in accordance with Section 3.10. Grout shall be prevented from bonding with the flue liner so that the flue liner is free to move with thermal expansion. For chimneys greater than 1000 mm wide, two additional Dia 12 mm vertical bars shall be provided for each additional 1000 mm in width or fraction thereof.

13.3.2 **Horizontal reinforcing.** Vertical reinforcement shall be placed enclosed within 6 mm ties, or other reinforcing of equivalent net cross-sectional area, spaced not to exceed 450 mm o.c. in concrete, or placed in the bed joints of unit masonry, at a minimum of every 450 mm of vertical height. Two such ties shall be provided at each bend in the vertical bars.

SECTION 13.4
SEISMIC ANCHORAGE

13.4.0 Masonry and concrete chimneys and foundations in Seismic Design Category D shall be anchored at each floor, ceiling or roof line more than 1800 mm above grade, except where constructed completely within the exterior walls. Anchorage shall conform to the following requirements.

13.4.1 **Anchorage.** Two 5 mm by 25 mm straps shall be embedded a minimum of 300 mm into the chimney. Straps shall be hooked around the outer bars and extend 150 mm beyond the bend. Each strap shall be fastened to a minimum of four floor joists with two 13 mm bolts.

SECTION 13.5
CORBELING

13.5.0 Masonry chimneys shall not be corbeled more than half of the chimney's wall thickness from a wall or foundation, nor shall a chimney be corbeled from a wall or foundation that is less than 300 mm in thickness unless it projects equally on each side of the wall, except that on the second story of a two-story dwelling, corbeling of chimneys on the exterior of the enclosing walls is permitted to equal the wall thickness. The projection of a single course shall not exceed one-half the unit height or one-third of the unit bed depth, whichever is less.

SECTION 13.6
CHANGES IN DIMENSION

13.6.0 The chimney wall or chimney flue lining shall not change in size or shape within 150 mm above or below where the chimney passes through floor components, ceiling components or roof components.

SECTION 13.7
OFFSETS

13.7.0 Where a masonry chimney is constructed with a fireclay flue liner surrounded by one wythe of masonry, the maximum offset shall be such that the centerline of the flue above the offset does not extend beyond the center of the chimney wall below the offset. Where the chimney offset is supported by masonry below the offset in an approved manner, the maximum offset limitations shall not apply. Each individual corbeled masonry course of the offset shall not exceed the projection limitations specified in Section 13.5.

SECTION 13.8
ADDITIONAL LOAD

13.8.0 Chimneys shall not support loads other than their own weight unless they are designed and constructed to support the additional load. Masonry chimneys are permitted to be constructed as part of the masonry walls of the building.

SECTION 13.9
TERMINATION

13.9.0 Chimneys shall extend at least 600 mm higher than any portion of the building within 3000 mm, but shall not be less than 900 mm above the highest point where

the chimney passes through the roof.

13.9.1 **Spark arrestors.** Where a spark arrestor is installed on a masonry chimney, the spark arrestor shall meet all of the following requirements:

1. The net free area of the arrestor shall not be less than four times the net free area of the outlet of the chimney flue it serves.
2. The arrestor screen shall have heat and corrosion resistance equivalent to 19-gage galvanized steel or 24-gage stainless steel.
3. Openings shall not permit the passage of spheres having a diameter greater than 13 mm nor block the passage of spheres having a diameter less than 11 mm.
4. The spark arrestor shall be accessible for cleaning and the screen or chimney cap shall be removable to allow for cleaning of the chimney flue.

SECTION 13.10
WALL THICKNESS

13.10.0 Masonry chimney walls shall be constructed of concrete, solid masonry units or hollow masonry units grouted solid with not less than 100 mm nominal thickness.

SECTION 13.11
FLUE LINING (MATERIAL)

13.11.0 Masonry chimneys shall be lined. The lining material shall be appropriate for the type of appliance connected, according to the terms of the appliance listing and the manufacturer's instructions.

13.11.1 **Residential-type appliances (general).** Flue lining systems shall comply with one of the following:

1. Clay flue lining complying with the requirements of ASTM C 315, or equivalent.
2. Listed chimney lining systems complying with UL 1777.
3. Factory-built chimneys or chimney units listed for installation within masonry chimneys.
4. Other approved materials that will resist corrosion, erosion, softening or cracking from flue gases and condensate at temperatures up to 982 °C.

13.11.1.1 **Flue linings for specific appliances.** Flue linings other than those covered in Section 13.11.1 intended for use with specific appliances shall comply with Section 13.11.1.2 through 13.11.1.4, 13.11.2, 13.11.3.

13.11.1.2 **Gas appliances.** Flue lining systems for gas appliances shall be installed in an approved method.

13.11.1.3 **Pellet fuel-burning appliances.** Flue lining and vent systems for use in masonry chimneys with pellet fuel-burning appliances shall be limited to flue lining systems complying with Section 13.11.1 and pellet vents listed for installation within masonry chimneys (see 13.11.1.5 for marking).

13.11.1.4 **Oil-fired appliances approved for use with L-vent.** Flue lining and vent systems for use in masonry chimneys with oil-fired appliances approved for use with Type

L-vent shall be limited to flue lining systems complying with Section 13.11.1 and listed chimney liners complying with UL 641 see Section 13.11.1.5 for marking).

13.11.1.5 **Notice of usage.** When a flue is relined with a material not complying with Section 13.11.1, the chimney shall be plainly and permanently identified by a label attached to a wall, ceiling or other conspicuous location adjacent to where the connector enters the chimney. The label shall include the following message or equivalent language: "This chimney is for use only with (type or category of appliance) that burns (type of fuel). Do not connect other types of appliances."

13.11.2 Concrete and masonry chimneys for medium-heat appliances.

13.11.2.1 **General.** Concrete and masonry chimneys for medium-heat appliances shall comply with Section 13.1 through 13.5.

13.11.2.2 **Construction.** Chimneys for medium-heat appliances shall be constructed of solid masonry units or of concrete with walls a minimum of 200 mm thick, or with stone masonry a minimum of 300 mm thick.

13.11.2.3 **Lining.** Concrete and masonry chimneys shall be lined with an approved medium-duty refractory brick a minimum of 110 mm thick laid on the 110 mm in an approved medium-duty refractory mortar. The lining shall start 600 mm or more below the lowest chimney connector entrance. Chimneys terminating 7500 mm or less above a chimney connector entrance shall be lined to the top.

13.11.2.4 **Multiple passageway.** Concrete and masonry chimneys containing more than one passageway shall have the liners separated by a minimum 100 mm concrete or solid masonry wall.

13.11.2.5 **Termination height.** Concrete and masonry chimneys for medium-heat appliances shall extend a minimum of 3000 mm higher than any portion of any building within 7500 mm.

13.11.2.6 **Clearance.** A minimum clearance of 100 mm shall be provided between the exterior surfaces of a concrete or masonry chimney for medium-heat appliances and combustible material.

13.11.3 Concrete and masonry chimneys for high-heat appliances.

13.11.3.1 **General.** Concrete and masonry chimneys for high-heat appliances shall comply with Section 13.1 through 13.5.

13.11.3.2 **Construction.** Chimneys for high-heat appliances shall be constructed with double walls of solid masonry units or of concrete, each wall to be a minimum of 200 mm thick with a minimum airspace of 50 mm between the walls.

13.11.3.3 **Lining.** The inside of the interior wall shall be lined with an approved high-duty refractory brick, a minimum 110 mm thick laid on the 110 mm bed in an approved high-duty refractory mortar. The lining shall start at the base of the chimney and extend continuously to the top.

13.11.3.4 **Termination height.** Concrete and masonry chimneys for high-heat appliances shall extend a minimum of 6000 mm higher than any portion of any building within 15000 mm.

13.11.3.5 **Clearance.** Concrete and masonry chimneys for high-heat appliances shall have approved clearance from buildings and structures to prevent overheating combustible materials, permit inspection and maintenance operations on the chimney and prevent danger of burns to persons.

SECTION 13.12
FLUE LINING (INSTALLATION)

13.12.1 Flue liners shall be installed in accordance with ASTM C 1283 and extend from a point not less than 200 mm below the lowest inlet or, in the case of fireplaces, from the top of the smoke chamber, to a point above the enclosing walls. The lining shall be carried up vertically, with a maximum slope no greater than 0.52 rad (30 degrees) from the vertical.

13.12.2 Fireclay flue liners shall be laid in medium-duty refractory mortar conforming to ASTM C 199, with tight mortar joints left smooth on the inside and installed to maintain an airspace or insulation not to exceed the thickness of the flue liner separating the flue liners from the interior face of the chimney masonry walls. Flue lining shall be supported on all sides. Only enough mortar shall be placed to make the joint and hold the liners in position.

SECTION 13.13
ADDITIONAL REQUIREMENTS

13.13.1 **Listed materials.** Listed materials used as flue linings shall be installed in accordance with the terms of their listings and the manufacturer's instructions.

13.13.2 **Space around lining.** The space surrounding a chimney lining system or vent installed within a masonry chimney shall not be used to vent any other appliance.

Exception: This shall not prevent the installation of a separate flue lining in accordance with the manufacturer's instructions.

SECTION 13.14
MULTIPLE FLUES

13.14.1 When two or more flues are located in the same chimney, masonry wythes shall be built between adjacent flue linings. The masonry wythes shall be at least 100 mm thick and bonded into the walls of the chimney.

Exception: When venting only one appliance, two flues are permitted to adjoin each other in the same chimney with only the flue lining separation between them. The joints of the adjacent flue linings shall be staggered at least 100 mm.

SECTION 13.15
FLUE AREA (APPLIANCE)

13.15.1 Chimney flues shall not be smaller in area than the area of the connector from the appliance. Chimney flues connected to more than one appliance shall not be less than the area of the largest connector plus 50% of the areas of additional chimney connectors.

Exceptions:

1. Chimney flues serving gas and oil-fired appliances sized in accordance with NFPA 31.

SECTION 13.16
FLUE AREA (MASONRY FIREPLACE)

13.16.0 Flue sizing for chimneys serving fireplaces shall be in accordance with Section 13.16.1 or 13.16.2.

13.16.1 **Minimum area.** Round chimney flues shall have a minimum net cross-sectional area of at least $1/12$ of the fireplace opening. Square chimney flues shall have a minimum net cross-sectional area of at least $1/10$ of the fireplace opening. Rectangular chimney flues with an aspect ratio less than 2 to 1 shall have a minimum net cross-sectional area of at least $1/10$ of the fireplace opening. Rectangular chimney flues with an aspect ratio of 2 to 1 or more shall have a minimum net cross-sectional area of at least $1/8$ of the fireplace opening.

13.16.2 **Determination of minimum area.** The minimum net cross-sectional area of the flue shall be determined in accordance with Figure 13.16.1. A flue size providing at least the equivalent net cross-sectional area shall be used. Cross-sectional areas of clay flue linings are as provided in Tables 13.16.1 and 13.16.2 or as provided by the manufacturer or as measured in the field. The height of the chimney shall be measured from the firebox floor to the top of the chimney flue.

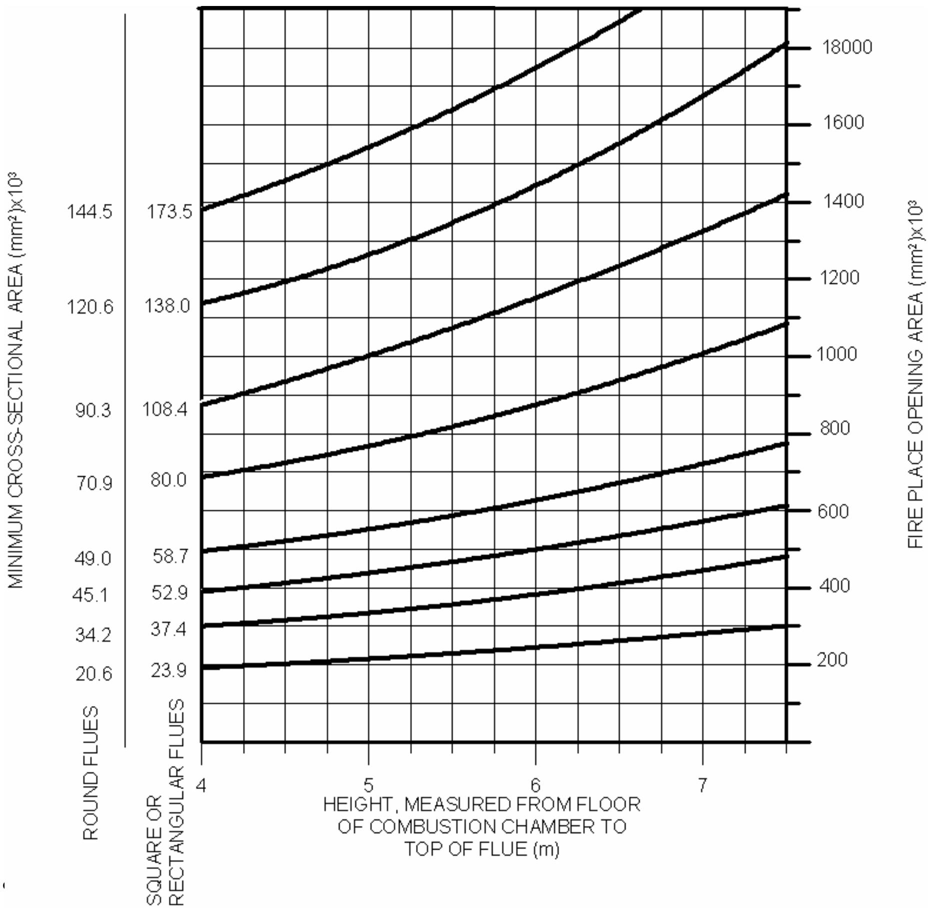

FIGURE 13.16.1
FLUE SIZES FOR MASONRY CHIMNEYS

TABLE 13.16.1
NET CROSS-SECTIONAL AREA OF ROUND FLUE SIZES[a]

FLUE SIZE, INSIDE DIAMETER (mm)	CROSS-SECTIONAL AREA (square mm)
150	17670
175	24050
200	31415
250	49090
269	56830
300	70685
375	110445
450	159045

a. Flue sizes are based on ASTM C 315.

TABLE 13.16.2
NET CROSS-SECTIONAL AREA OF SQUARE AND RECTANGULAR FLUE SIZES[a]

FLUE SIZE (mm)	CROSS-SECTIONAL AREA (square mm)
110 x 325	21250
190 x 190	23125
210 x 210	29375
190 x 290	36250
210 x 325	46250
190 x 390	51250
290 x 290	56875
210 x 440	63125
325 x 325	76250
290 x 390	77500
325 x 440	103125
390 x 390	105000
390 x 490	133750
440 x 440	141250
490 x 490	168125
500 x 500	178750

a. Flue sizes are based on ASTM C 315.

SECTION 13.17
INLET

13.17.1 Inlets to masonry chimneys shall enter from the side. Inlets shall have a thimble of fireclay, rigid refractory material or metal that will prevent the connector from pulling out of the inlet or from extending beyond the wall of the liner.

SECTION 13.18
MASONRY CHIMNEY CLEANOUT OPENINGS

13.18.1 Cleanout openings shall be provided within 150 mm of the base of each flue within every masonry chimney. The upper edge of the cleanout shall be located at least 150 mm below the lowest chimney inlet opening. The height of the opening shall be at least 150 mm. The cleanout shall be provided with a noncombustible cover.

Exception: Chimney flues serving masonry fireplaces, where cleaning is possible through the fireplace opening.

SECTION 13.19
CHIMNEY CLEARANCES

13.19.1 Any portion of a masonry chimney located in the interior of the building or within the exterior wall of the building shall have a minimum airspace clearance to combustibles of 50 mm. Chimneys minimum airspace clearance of 25 mm. The airspace shall not be filled, except to provide fireblocking in accordance with Section 13.20.

Exceptions:

1. Masonry chimneys equipped with a chimney lining system listed and labeled for use in chimneys in contact with combustibles in accordance with UL 1777, and installed in accordance with the manufacturer's instructions, are permitted to have combustible material in contact with their exterior surfaces.
2. Where masonry chimneys are constructed as part of masonry or concrete walls, combustible materials shall not be in contact with the masonry or concrete wall less than 300 mm from the inside surface of the nearest flue lining.
3. Exposed combustible trim and the edges of sheathing materials, such as wood siding, are permitted to abut the masonry chimney sidewalls, in accordance with Figure 13.19.1, provided such combustible trim or sheathing is a minimum of 300 mm from the inside surface of the nearest flue lining. Combustible material and trim shall not overlap the corners of the chimney by more than 25 mm.

SECTION 13.20
CHIMNEY FIREBLOCKING

13.20.1 All spaces between chimneys and floors and ceilings through which chimneys pass shall be fireblocked with noncombustible material securely fastened in place. The fireblocking of spaces between wood joists, beams or headers shall be to a depth of 25 mm and shall only be placed on strips of metal or metal lath laid across the spaces between combustible material and the chimney.

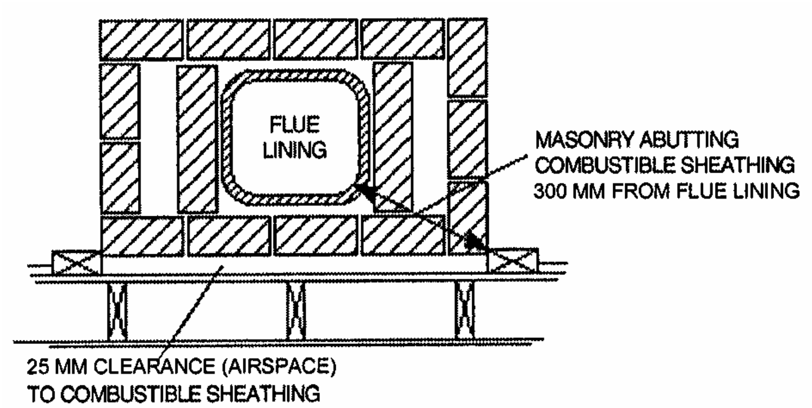

FIGURE 13.19.1
ILLUSTRATION OF EXCEPTION TO CHIMNEY CLEARANCE PROVISION

CHAPTER 14
MASONRY VENEER

SECTION 14.1
GENERAL

14.1.1 **Scope.** This section provides requirements for design and detailing of anchored masonry veneer and adhered masonry veneer.

14.1.1.1 The provisions of Chapter 1 to Chapter 5, excluding Section 1.3(item 6), 1.4, 3.13, 4.13 and 5.2 shall apply to design of anchored and adhered veneer.

14.1.1.2 Section 4.1.2 and 4.1.9 shall not apply to adhered veneer.

14.1.2 **Design of anchored veneer.** Anchored veneer shall meet the requirements of Section 14.1.5 and shall be designed rationally by Section 14.2.1 or detailed by the prescriptive requirements of Section 14.2.2.

14.1.3 **Design of adhered veneer.** Adhered veneer shall meet the requirements of Section 14.1.5 and shall be designed rationally by Section 14.3.1 or detailed by the prescriptive requirements of Section 14.3.2.

14.1.4 **Dimension stone.** Dimension stone veneer is not covered under this Code. Any such system shall be considered a Special System and submitted to the Building Official in accordance with Section 1.3.5.

14.1.5 **General design requirements**

14.1.5.1 Design and detail the backing system of exterior veneer to resist water penetration. Exterior sheathing shall be covered with a water-resistant membrane unless the sheathing is water resistant and the joints are sealed.

14.1.5.2 Design and detail flashing and weep holes in exterior veneer wall systems to resist water penetration into the building interior. Weepholes shall be at least 5 mm in diameter and spaced less than 800 mm on center.

14.1.5.3 Design and detail the veneer to accommodate differential movement.

SECTION 14.2
ANCHORED VENEER

14.2.1 **Alternative design of anchored masonry veneer.** The alternative design of anchored veneer, which is permitted under Section1.3.5, shall satisfy the following conditions:

(a) Loads shall be distributed through the veneer to the anchors and the backing using principles of mechanics.

(b) Out-of-plane deflection of the backing shall be limited to maintain veneer stability.

(c) All masonry, other than veneer, shall meet the provisions of Section 1.2, excluding Section 1.2.5 and 1.2.6.

(d) The veneer is not subject to the flexural tensile stress provisions of Section 7.2.

14.2.2 Prescriptive requirements for anchored masonry veneer

14.2.2.1 Prescriptive requirements for anchored masonry veneer shall not be used in areas where the basic wind speed exceeds 145 km/h as given in SBC 301.

14.2.2.2 Connect anchored veneer to the backing with anchors that comply with Section 14.2.2.5 and 3.11.

14.2.2.3 Vertical support of anchored masonry veneer

14.2.2.3.1 The weight of anchored veneer shall be supported vertically on concrete or masonry foundations or other noncombustible structural supports.

14.2.2.3.1.1 If anchored veneer with a backing of cold-formed steel framing exceeds the height above the noncombustible foundation given in Table 14.2.1, the weight of the veneer shall be supported by noncombustible construction for each story above the height limit given in Table 14.2.1.

Table 14.2.1 – Height limit from foundation

Height at plate, m	Height at gable, m
9.00	11.00

14.2.2.3.2 When anchored veneer is supported by floor construction, the floor shall be designed to limit deflection as required in Section 4.1.5.1.

14.2.2.3.3 Provide noncombustible lintels or supports attached to noncombustible framing over all openings where the anchored veneer is not self-supporting. The deflection of such lintels or supports shall conform to the requirements of Section 4.1.5.1.

14.2.2.4 **Masonry units** - Masonry units shall be at least 70 mm in actual thickness.

14.2.2.5 Anchor requirements

14.2.2.5.1 Corrugated sheet metal anchors

14.2.2.5.1.1 Corrugated sheet metal anchors shall be at least 22 mm wide, have a base metal thickness of at least 0.8 mm, and shall have corrugations with a wavelength of 7.5 to 12 mm and an amplitude of 1.5 to 2.5 mm.

14.2.2.5.1.2 Corrugated sheet metal anchors shall be placed as follows:

- **(a)** With solid units, embed anchors in the mortar joint and extend into the veneer a minimum of 38 mm, with at least 16 mm mortar cover to the outside face.
- **(b)** With hollow units, embed anchors in mortar or grout and extend into the veneer a minimum of 38 mm, with at least 16 mm mortar or grout cover to the outside face.

14.2.2.5.2 Sheet metal anchors

14.2.2.5.2.1 Sheet metal anchors shall be at least 23 mm wide, have a base metal thickness of at least 1.5 mm and shall:

- **(a)** Have corrugations as given in Section14.2.2.5.1.1, or
- **(b)** Be bent, notched, or punched to provide equivalent performance in pull-out or push-through.

14.2.2.5.2.2 Sheet metal anchors shall be placed as follows:

(a) With solid units, embed anchors in the mortar joint and extend into the veneer a minimum of 38 mm, with at least 16 mm mortar cover to the outside face.

(b) With hollow units, embed anchors in mortar or grout and extend into the veneer a minimum of 38 mm, with at least 16 mm mortar or grout cover to the outside face.

14.2.2.5.3 Wire anchors

14.2.2.5.3.1 Wire anchors shall be at least wire size WD 4 and have ends bent to form an extension from the bend at least 50.0 mm long.

14.2.2.5.3.2 Wire anchors shall be placed as follows:

(a) With solid units, embed anchors in the mortar joint and extend into the veneer a minimum of 40 mm, with at least 16 mm mortar cover to the outside face.

(b) With hollow units, embed anchors in mortar or grout and extend into the veneer a minimum of 40 mm, with at least 16 mm mortar or grout cover to the outside face.

14.2.2.5.4 Joint reinforcement

14.2.2.5.4.1 Ladder-type or tab-type joint reinforcement is permitted. Cross wires used to anchor masonry veneer shall be at least wire size WD 4 and shall be spaced at a maximum of 400 mm on center. Cross wires shall be welded to longitudinal wires, which shall be at least wire size WD 4.

14.2.2.5.4.2 Embed longitudinal wires of joint reinforcement in the mortar joint with at least 16 mm mortar cover on each side.

14.2.2.5.5 Adjustable anchors

14.2.2.5.5.1 Sheet metal and wire components of adjustable anchors shall conform to the requirements of Section 14.2.2.5.1, 14.2.2.5.2, or 14.2.2.5.3. Adjustable anchors with joint reinforcement shall also meet the requirements of Section 14.2.2.5.4.

14.2.2.5.5.2 Maximum clearance between connecting parts of the tie shall be 1.5 mm.

14.2.2.5.5.3 Adjustable anchors shall be detailed to prevent disengagement.

14.2.2.5.5.4 Pintle anchors shall have at least two pintle legs of wire size WD 5 each and shall have an offset not exceeding 30 mm.

14.2.2.5.5.5 Adjustable anchors of equivalent strength and stiffness to those specified in Sections 14.2.2.5.5.1 through 14.2.2.5.5.5 are permitted.

14.2.2.5.6 Anchor spacing

14.2.2.5.6.1 For adjustable two-piece anchors, anchors of wire size WD 4, and 1 mm corrugated sheet metal anchors, provide at least one anchor for each 0.25 m^2 of wall area.

14.2.2.5.6.2 For all other anchors, provide at least one anchor for each 0.3 m^2 of wall area.

14.2.2.5.6.3 Space anchors at a maximum of 810 mm horizontally and 450 mm vertically.

14.2.2.5.6.4 Provide additional anchors around all openings larger than 400 mm in either dimension. Space anchors around perimeter of opening at a maximum of 1 m on center. Place anchors within 300 mm of openings.

14.2.2.5.7 **Joint thickness for anchors** – Mortar bed joint thickness shall be at least twice the thickness of the embedded anchor.

14.2.2.6 **Masonry veneer anchored to steel backing**

14.2.2.6.1 Attach veneer with adjustable anchors.

14.2.2.6.2 Attach each anchor to steel framing with corrosion-resistant screws that have a minimum nominal shank diameter of 5 mm.

14.2.2.6.3 Cold-formed steel framing shall be corrosion resistant and have a minimum base metal thickness of 1 mm.

14.2.2.6.4 Maintain a 110 mm maximum distance between the inside face of the veneer and the steel framing. Maintain a 25 mm minimum air space.

14.2.2.7 **Masonry veneer anchored to masonry or concrete backing**

14.2.2.7.1 Attach veneer to masonry backing with wire anchors, adjustable anchors, or joint reinforcement. Attach veneer to concrete backing with adjustable anchors.

14.2.2.7.2 Maintain a 110 mm maximum distance between the inside face of the veneer and the outside face of the masonry or concrete backing. Maintain a 25 mm minimum air space.

14.2.2.8 **Veneer laid in other than running bond**

Anchored veneer laid in other than running bond shall have joint reinforcement of at least one wire, of size WD 4, spaced at a maximum of 450 mm on center vertically.

14.2.2.9 **Requirements in seismic areas**

14.2.2.9.1 **Seismic Design Category C**

14.2.2.9.1.1 The requirements of this section apply to anchored veneer for buildings in Seismic Design Category C.

14.2.2.9.1.2 Isolate the sides and top of anchored veneer from the structure so that vertical and lateral seismic forces resisted by the structure are not imparted to the veneer.

14.2.2.9.2 **Seismic Design Category D**

14.2.2.9.2.1 The requirements for Seismic Design Category C and the requirements of this section apply to anchored veneer for buildings in Seismic Design Category D.

14.2.2.9.2.2 Support the weight of anchored veneer for each story independent of other stories.

14.2.2.9.2.3 Reduce the maximum wall area supported by each anchor to 75 % of that required in Sections 14.2.2.5.6.1 and 14.2.2.5.6.2. Maximum horizontal and vertical spacing are unchanged.

14.2.2.9.2.4 Provide continuous, single-wire joint reinforcement of minimum wire size WD 4 at a maximum spacing of 450 on center vertically.

SECTION 14.3
ADHERED VENEER

14.3.1 **Alternative design of adhered masonry veneer**. The alternative design of adhered veneer, which is permitted under Section 1.3.5, shall satisfy the following conditions:

(a) Loads shall be distributed through the veneer to the backing using principles of mechanics.

(b) Out-of-plane curvature shall be limited to prevent veneer unit separation from the backing.

(c) All masonry, other than veneer, shall meet the provisions of Section 1.2, excluding Sections 1.2.5 and 1.2.6.

(d) The veneer is not subject to the flexural tensile stress provisions of Section 7.2.

14.3.2 Prescriptive requirements for adhered masonry veneer

14.3.2.1 **Unit sizes —** Adhered veneer units shall not exceed 65 mm in specified thickness, 910 mm in any face dimension, nor more that 0.45 m^2 in total face area, and shall not weigh more than 710 Pa .

14.3.2.2 **Wall area limitations —** The height length and area of adhered veneer shall not be limited except as required to control restrained differential movement stresses between veneer and backing.

14.3.2.3 **Backing —** Backing shall provide a continuous, moisture-resistant surface to receive the adhered veneer. Backing is permitted to be masonry, concrete, or metal lath and Portland cement plaster applied to masonry, concrete or steel framing.

14.3.2.4 Adhesion developed between adhered veneer units and backing shall have a shear strength of at least 0.35 MPa based on gross unit surface area when tested in accordance with ASTM C 482, or shall be adhered in compliance with Section 4.1.2.6.

REFERENCED STANDARDS

These are the standards referenced within SBC 305. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title. The application of the referenced standards shall be as specified in SBC.

1. ACI, 530/ASCE 5/TMS 402, Building Code Requirements for Masonry Structures and Commentary and Specification for Masonry Structures and Commentary, American Concrete Institute (ACI), 38800 Country Club Dr., Farmington Hills, MI 48331, U.S.A.
2. ACI, 530.1/ASCE 6/TMS 602, Building Code Requirements for Masonry Structures and Commentary and Specification for Masonry Structures and Commentary, American Concrete Institute (ACI), 38800 Country Club Dr., Farmington Hills, MI 48331, U.S.A.
3. ANSI, A42.2, Portland Cement and Portland Cement-lime Plastering, Exterior (STUCCO) and Interior, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
4. ANSI, A42.3, Lathing and Furring for Portland Cement-lime Plastering, Exterior (STUCCO) and interior, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
5. ANSI, A108.1A, Specifications for Installation of Ceramic Tile in the Wet-set Method, with Portland Cement Mortar, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
6. ANSI, A108.1B, Specifications for Installation of Ceramic Tile on a Cured Portland Cement Mortar Setting Bed with Dry-set or Latex Portland Cement Mortar, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
7. ANSI, A108.4, Specifications for Installation of Ceramic Tile with Organic Adhesives or Water Cleanable Tile Setting Epoxy Adhesive, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
8. ANSI, A108.5, Ceramic Tile, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
9. ANSI, A108.6, Specifications for Installation of Ceramic Tile with Tile with Chemical Resistant, Water Cleanable Tile Setting and Grouting Epoxy, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
10. ANSI, A108.7, Ceramic Tile, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
11. ANSI, A108.8, Specifications for Installation of Ceramic Tile with Chemical Resistant Furan Mortar and Grout, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
12. ANSI, A108.9, Ceramic Tile, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
13. ANSI, A108.10, Specifications for Installation of Grout in Tilework, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
14. ANSI, A118.1, Specifications for Dry-Set Portland Cement Mortar, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
15. ANSI, A118.2, Specifications for Conductive Dry-Set Portland Cement Mortar, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
16. ANSI, A118.3, Specifications for Chemical Resistant, Water Cleanable Tile-Setting and Grouting Epoxy and Water, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.

17. ANSI, A118.4, Specifications for Latex Portland Cement Mortar, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
18. ANSI, A118.5, Specifications for Chemical Resistant Furan Resin Mortars and Grouts for Tile Installation, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
19. ANSI, A118.6, Specifications for Ceramic Tile Grouts, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
20. ANSI, A118.8, Specifications for Modified Epoxy Emulsion Mortar Grout, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
21. ANSI, A136.1, Ceramic Tile, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
22. ANSI, A137.1, American National Standard Specifications for Ceramic Tile, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, U.S.A.
23. ASCE, 7, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers, Structural Engineering Institute, 1801 Alexander Bell Drive, Reston, VA 20191-4400, U.S.A.
24. ASTM, C 27, Standard Classification of Fireclay and High-Alumina Refractory Brick, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
25. ASTM, C 34, Standard Specification for Structural Clay Load Bearing-Wall Tile, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
26. ASTM, A 36, Standard Specification for Carbon Structural Steel, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
27. ASTM, C 55, Standard Specification for Concrete Building Brick, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
28. ASTM, C 56, Standard Specification for Structural Clay Non-Load-Bearing Tile, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
29. ASTM, C 62, Standard Specification for Building Brick (Solid Masonry Units) Made from Clay or Shale, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
30. ASTM, C 67, Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
31. ASTM, C 73, Standard Specification for Calcium Silicate Brick (Sand-Lime Brick), ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
32. ASTM, A 82, Standard Specification for Steel Wire, Plain, for Concrete Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
33. ASTM, C 90, Standard Specification for Loadbearing Concrete Masonry Units, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
34. ASTM, C 91, Standard Specification for Masonry Cement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
35. ASTM, E 111, Standard Test Methods for Young's Modulus, Tangent Modulus, and Chord Modulus, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.

36. ASTM, E 119, Standard Specification for Fire Tests of Building Construction and Materials, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
37. ASTM, A 123, Standard Specification for Apparatus for Determination of Water by Distillation, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
38. ASTM, C 126, Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
39. ASTM, C 140, Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
40. ASTM, C 150, Standard Specification for Portland Cement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
41. ASTM, A 153, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
42. ASTM, A 167, Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
43. ASTM, A 185, Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
44. ASTM, C 199, Standard Test Methods for Pier Test for Refractory Mortars, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
45. ASTM, C 207, Standard Specification for Hydrated Lime for Masonry Purposes, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
46. ASTM, C 212, Standard Specification for Structural Clay Facing Tile, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
47. ASTM, C 216, Standard Specification for Facing Brick (Solid Masonry Units) Made from Clay or Shale, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
48. ASTM, C 270, Standard Specification for Mortar Unit Masonry, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
49. ASTM, C 315, Standard Specification for Clay Flue Liners, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
50. ASTM, E 328, Standard Test Methods for Stress Relaxation Tests for Materials and Structures, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
51. ASTM, A 366, Standard Specification for Convection Oven Gas or Electric, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
52. ASTM, A 416, Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
53. ASTM, A 421, Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.

54. ASTM, A 426-99, Test Method for Drying Shrinkage of Concrete Block, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
55. ASTM, C 476, Standard Specification for Grout for Masonry, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
56. ASTM, C 482, Standard Test Method for Bond Strength of Ceramic Tile to Portland Cement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
57. ASTM, E 488-96, Test Methods for Strength of Anchors in Concrete and Masonry Elements, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
58. ASTM, A 496, Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
59. ASTM, C 503, Standard Specification for Marble Dimension Stone, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
60. ASTM, A 510, Standard Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
61. ASTM, C 568, Standard Specification for Limestone Dimension Stone, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
62. ASTM, C 595, Standard Specification for Blended Hydraulic Cements, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
63. ASTM, A 615, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
64. ASTM, C 615, Standard Specification for Granite Dimension Stone, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
65. ASTM, A 616, Standard Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement (Withdraw 1999), ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
66. ASTM, C 616, Standard Specification for Quartz-Based Dimension Stone, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
67. ASTM, C 629, Standard Specification for Slate Dimension Stone, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
68. ASTM, A 641, Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
69. ASTM, C 652, Standard Specification for Hollow Brick (Hollow Masonry Units) Made from Clay or Shale, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
70. ASTM, A 653, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron, Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
71. ASTM, A 706, Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.

72. ASTM, A 706 A, Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
73. ASTM, A 706 M, Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
74. ASTM, A 722, Standard Specification for Uncoated High-Strength Steel Bars for Prestressing Concrete, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
75. ASTM, A 767, Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
76. ASTM, A 775, Standard Specification for Epoxy-Coated Steel Reinforcing Bars, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
77. ASTM, C 744, Standard Specification for Prefaced Concrete and Calcium Silicate Masonry Units, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
78. ASTM, A 884, Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
79. ASTM, C 887, Standard Specification for Packaged, Dry, Combined Materials for Surface Bonding Mortar, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
80. ASTM, A 899, Standard Specification for Steel Wire, Epoxy-Coated, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
81. ASTM, C 946, Standard Practice for Construction of Dry-Stacked, Surface Bonded Walls, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
82. ASTM, A 951, Standard Specification for Steel Wire for Masonry Joint Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
83. ASTM, A 996, Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
84. ASTM, C 1019, Standard Test Method for Sampling and Testing Grout, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
85. ASTM, C 1088, Standard Specification for Thin Veneer Brick Units Made from Clay or Shale, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
86. ASTM, C 1261, Standard Specification for Firebox Brick for Residential Fireplaces, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
87. ASTM, C 1283, Standard Practice for Installing Clay Flue Lining, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
88. ASTM, C 1314, Standard Test Method for Compressive Strength of Masonry Prisms, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
89. ASTM, C 1329, Standard Specification for Mortar Cement, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.

90. ASTM, E 1602, Standard Specification for Construction of Solid Fuel Burning Masonry Heaters, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
91. AWS, D 1.4-98, Structural Welding Code – Reinforcing Steel, American Welding Society, 550 N.W. LeJune Road, Miami, FL. 33126, U.S.A.
92. NFPA, 31, Standard for the Installation of Oil-Burning Equipment, ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959, U.S.A.
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